IEC/PAS 60044-5

Edition 1.0
2002-07

Instrument transformers –

Part 5: Capacitor voltage transformers

Transformateurs de mesure –

Partie 5: Transformateurs condensateurs de tension

PUBLICLY AVAILABLE SPECIFICATION

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

A PAS is a technical specification not fulfilling the requirements for a standard, but made available to the public.

IEC-PAS 60044-5 has been processed by IEC technical committee 38: Instrument transformers.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:
Draft PAS	**Report on voting**
38/279/PAS	38/284/RVD

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INSTRUMENT TRANSFORMERS –
Part 5: Capacitor voltage transformers

1 Scope

This PAS which is a part of International Standard IEC 60044 applies to new single-phase capacitor voltage transformers connected between line and ground for system voltages $U_m \geq$ 72,5 kV at power frequencies from 15 Hz to 100 Hz. They are intended to supply a low voltage for measurement, control and protective functions.

The capacitor voltage transformer can be equipped with or without carrier-frequency accessories for power line carrier-frequency (PLC) application at carrier frequencies from 30 kHz to 500 kHz.

The future standard that should supersede the present PAS will replace the IEC 60186 regarding capacitor voltage transformers.

Three standards formed the basis for this IEC-PAS 60044-5:

– IEC 60044-2; concerning inductive voltage transformers;
– IEC 60358, concerning coupling capacitors and capacitor dividers;
– IEC 60481, concerning coupling devices for power line carrier (PLC) systems.

The application measurement function includes both indication measuring and revenue measuring.

NOTE Diagrams of capacitor voltage transformer to which this document applies are given in figures A.1 and A.2.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60028:1925, *International standard of resistance for copper*

IEC 60038:1983, *IEC standard voltages*

IEC 60044-2:1997, *Instrument transformers – Part 2: Inductive voltage transformers*

IEC 60050-321:1986, *International Electrotechnical Vocabulary – Chapter 321: Instrument transformers*

IEC 60050-436:1990, *International Electrotechnical Vocabulary – Chapter 436: Power capacitors*

IEC 60050-601:1985, *International Electrotechnical Vocabulary – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60050-604:1987, *International Electrotechnical Vocabulary – Chapter 604: Generation, transmission and distribution of electricity – Operation*

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*

IEC 60233:1974, *Tests on hollow insulators for use in electrical equipment*

IEC 60270:1981, *Partial discharge measurements*

IEC 60358:1990, *Coupling capacitors and capacitor dividers*

IEC 60481:1974, *Coupling devices for power line carrier systems*

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

CISPR 18-2:1986, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

3 Definitions

For the purpose of this part of IEC 60044, the following definitions shall apply. Some of these definitions are identical with or are similar to those of IEC 60050, Chapters 321, 436, 601 and 604. These are indicated by the relevant IEV reference number in brackets.

3.1 General definitions

3.1.1 capacitor voltage transformer (CVT)

a voltage transformer comprising a capacitor divider unit and an electromagnetic unit so designed and interconnected that the secondary voltage of the electromagnetic unit is substantially proportional to the primary voltage, and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections and rated frequency. [IEV 321-03-14 modified]

3.1.2 rated frequency of a capacitor voltage transformer (f_R)

the frequency for which the capacitor voltage transformer has been designed.

3.1.3 standard reference range of frequency

the range of frequency for which the rated accuracy is applicable.

3.1.4 rated primary voltage (U_{PR})

the r.m.s. value of the primary voltage which appears in the designation of the capacitor voltage transformer and on which its performance is based. [IEV 321-01-12 modified]

3.1.5 rated secondary voltage (U_{SR})

the r.m.s. value of the secondary voltage which appears in the designation of the capacitor voltage transformer and on which its performance is based. [IEV 321-01-16 modified]

3.1.6 secondary winding

the winding which supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus.

3.1.7 secondary circuit

the external circuit supplied by the secondary winding of a transformer.

3.1.8 actual transformation ratio

the ratio of the actual primary voltage to the actual secondary voltage. [IEV 321-01-18 modified]

3.1.9 rated transformation ratio (K_R)

the ratio of the rated primary voltage to the rated secondary voltage. [IEV 321-01-20 modified]

3.1.10 voltage error (ratio error) for steady state conditions (ε_u)

the error which a capacitor voltage transformer introduces into the measurement of a voltage and which arises when the actual transformation ratio is not equal to the rated transformation ratio K_R. [IEV 321-01-22 modified]

NOTE This definition is only related to components at rated frequency of both primary and secondary voltages, and does not take into account direct voltage components and residual voltages.

Voltage error $$\varepsilon_U = \frac{K_R U_S - U_P}{U_P} 100\,\%$$

where: K_R is the rated transformation ratio,

U_p is the actual primary voltage and

U_s is the actual secondary voltage when U_P is applied under the conditions of measurement.

3.1.11 phase displacement (φ_U)

the difference in phase between the primary and the secondary voltage phasors:

$$\varphi_U = (\varphi_S - \varphi_P)$$

The direction of the phasors being so chosen that the angle (φ_U) is zero for a perfect transformer. The phase displacement is said to be positive when the secondary voltage phasor (φ_S) leads the primary voltage phasor (φ_P). It is usually expressed in minutes or centiradians. [IEV 321-01-23 modified]

NOTE This definition is strictly correct for sinusoidal voltages only.

3.1.12 accuracy class

designation assigned to a capacitor voltage transformer, the errors of which remain within specified limits under prescribed conditions of use.

3.1.13 burden

admittance of the secondary circuit expressed in siemens and with an indication of the power factor (lagging or leading).

NOTE The burden is usually expressed as the apparent power in volt-amperes, absorbed at a specified power factor and at the rated secondary voltage.

3.1.14 rated burden

value of the burden on which the accuracy requirements of this document are based.

3.1.15 output

a) rated output
the value of the apparent power (in volt-amperes at a specified power factor), which the capacitor voltage transformer is intended to supply to the secondary circuit at the rated secondary voltage and with rated burden connected to it. [IEV 321-01-27 modified]

b) thermal limiting output
the value of the apparent power in volt-amperes referred to rated voltage which can be taken from a secondary winding, at rated primary voltage applied, without exceeding the limits of temperature rise of 6.5.

NOTE 1 In this condition the limits of error may be exceeded.

NOTE 2 In the case of more than one secondary winding, the thermal limiting output is to be given separately for each winding.

NOTE 3 The simultaneous use of more than one secondary winding is not permitted unless there is an agreement between the manufacturer and purchaser.

3.1.16 highest voltage for equipment (U_m)

the highest r.m.s. value of phase-to-phase voltage for which the equipment is designed and may be used in respect of its insulation.

3.1.17 rated insulation level

the combination of voltage values which characterises the insulation of a transformer with regard to its capability to withstand dielectric stresses.

3.1.18 isolated neutral system

a system where the neutral point is not intentionally connected to earth, except for high impedance connections for protection or measurement purposes. [IEV 601-02-24]

3.1.19 solidly earthed neutral system

a system whose neutral point(s) is(are) earthed directly. [IEV 601-02-25]

3.1.20 impedance earthed (neutral) system

a system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents. [IEV 601-02-26]

3.1.21 resonant earthed (neutral) system

system in which one or more neutral points are connected to earth through reactances which approximately compensate the capacitive component of a single-phase-to-earth fault current. [IEV 601-02-27]

NOTE With resonant earthing of a system, the residual current in the fault is limited to such an extent that an arcing fault in air is self-extinguishing.

3.1.22 earth fault factor

at a given location of a three-phase system, and for a given system configuration, the ratio of the highest r.m.s. phase-to-earth power frequency voltage on a healthy phase during a fault to earth affecting one or more phases at any point on the system to the r.m.s. phase-to-earth power frequency voltage which would be obtained at the given location in the absence of any such fault. [IEV 604-03-06]

3.1.23 earthed neutral system

system in which the neutral is connected to earth either solidly or through a resistance or reactance of sufficiently low value to reduce transient oscillations and to give a current sufficient for selective earth fault protection.

a) A three-phase system with effectively earthed neutral at a given location is a system characterized by an earth fault factor at this point which does not exceed 1,4.

NOTE This condition is obtained approximately when, for all system configurations, the ratio of zero-sequence reactance to the positive-sequence reactance is less than 3 and the ratio of zero-sequence resistance to positive-sequence reactance is less than one.

b) A three-phase system with non-effectively earthed neutral at a given location is a system characterized by an earth fault factor at this point that may exceed 1,4.

3.1.24 exposed installation

an installation in which the apparatus is subject to overvoltages of atmospheric origin.

NOTE Such installations are usually connected to overhead transmission lines either directly or through a short length of cable.

3.1.25 non-exposed installation

an installation in which the apparatus is not subject to overvoltages of atmospheric origin.

NOTE Such installations are usually connected to underground cable networks.

3.1.26 measuring capacitor voltage transformer

a capacitor voltage transformer intended to supply indicating instruments, integrating meters and similar apparatus.

3.1.27 protective capacitor voltage transformer

a capacitor voltage transformer intended to provide a supply to electrical protective relays.

3.1.28 residual voltage winding

the winding of a single-phase capacitor voltage transformer intended, in a set of three single-phase transformers, for connection in broken delta for the purpose of producing a residual voltage under earth-fault conditions.

3.1.29 rated voltage factor (F_V)

the multiplying factor to be applied to the rated primary voltage U_{PR} to determine the maximum voltage at which a transformer must comply with relevant thermal requirements for a specified time and with the relevant accuracy requirements.

3.1.30 rated temperature category of a capacitor voltage transformer

the range of temperature of the ambient air or of the cooling medium for which the capacitor voltage transformer has been designed.

3.1.31 high voltage terminal

terminal intended for connection to a line conductor of a network. [IEV 436-03-01]

3.1.32 ferro-resonance

sustained resonance of a circuit consisting of a capacitance with a non-linear saturable magnetic inductance.

NOTE The ferro-resonance can be initiated by switching operations on the primary side or secondary side.

3.1.33 transient response

the measured fidelity of the secondary-voltage waveform, compared with the voltage waveform at the high-voltage terminal under transient conditions.

3.1.34 mechanical stress

the stresses on different parts of the capacitor voltage transformer as a function of four main forces:

– forces on the terminals due to the line connections,

– forces due to the wind on the cross-section of the capacitor voltage transformer with and without line trap mounted on the top of the coupling capacitor,

– seismic forces and

– electro dynamic forces due to short circuit current.

3.1.35 voltage-connected CVT

the CVT is voltage-connected when there is only one connection to the high voltage line.

NOTE Under normal conditions the top connection carries only the current of the capacitor voltage transformer.

3.1.36 current-connected CVT

the CVT is current-connected when there are two connections to the high voltage line.

NOTE The terminals and the top connection are designed to carry under normal conditions the line current.

3.1.37 line trap-connected CVT

the CVT is line trap-connected when it supports a line trap on its top. In this case, the two connections to the line trap carry the HV line current and one connection from the line trap to the CVT carries the CVT current.

NOTE The pedestal mounting line traps in two phases are generating additional forces during a short circuit in more than one phase.

3.2 Capacitor voltage divider definitions

3.2.1 capacitor voltage divider

a capacitor stack forming an alternating voltage divider. [IEV 436-02-10]

3.2.2 capacitor element

a device consisting essentially of two electrodes separated by a dielectric. [IEV 436-01-03]

3.2.3 capacitor unit

an assembly of one or more capacitor elements in the same container with terminals brought out. [IEV 436-01-04]

NOTE A common type of unit for coupling capacitors has a cylindrical housing of insulating material and metallic flanges which serve as terminals.

3.2.4 capacitor stack

an assembly of capacitor units connected in series. [IEV 436-01-05]

NOTE The capacitor units are usually mounted in a vertical array.

3.2.5 capacitor

a general term used when it is not necessary to state whether reference is made to a capacitor unit or to a capacitor stack.

3.2.6 rated capacitance of a capacitor (C_R)

the capacitance value for which the capacitor has been designed.

NOTE This definition applies:

- for a capacitor unit, to the capacitance between the terminals of the unit;
- for a capacitor stack, to the capacitance between line and low voltage terminals or between line and earth terminals of the stack;
- for a capacitor divider, to the resultant capacitance: $C_R = C_1C_2/(C_1 + C_2)$.

3.2.7 coupling capacitor

a capacitor used for the transmission of signals in a power system. [IEV 436-02-11]

3.2.8 high voltage capacitor (of a capacitor divider) (C_1)

the capacitor connected between the line terminal and the intermediate voltage terminal of a capacitor divider. [IEV 436-02-12 modified]

3.2.9 intermediate voltage capacitor (of a capacitor divider) (C_2)

the capacitor connected between the intermediate voltage and the low voltage terminals of a capacitor divider. [IEV 436-02-13]

3.2.10 intermediate voltage terminal of a capacitor divider

a terminal intended for connection to an intermediate circuit, such as the electromagnetic unit of a capacitor voltage transformer. [IEV 436-03-03]

3.2.11 low voltage terminal of a capacitor divider

a terminal (N) intended for connection to earth either directly or via a drain coil of negligible value of impedance, at rated frequency, for power line carrier (PLC) application. [IEV 436-03-04 modified]

3.2.12 capacitance tolerance

the permissible difference between the actual capacitance and the rated capacitance under specified conditions. [IEV 436-04-01]

3.2.13 equivalent series resistance of a capacitor

virtual resistance which, if connected in series with an ideal capacitor of capacitance value equal to that of the capacitor in question, would have a power loss equal to the active power dissipated in that capacitor under specified operating conditions at a given high frequency.

3.2.14 high frequency capacitance

the effective capacitance at a given frequency resulting from the joint effect of the intrinsic capacitance and the self-inductance of a capacitor. [IEV 436-04-03]

3.2.15 intermediate voltage of a capacitor divider (U_C)

the voltage between the intermediate voltage terminal of the capacitor divider and the low voltage terminal, when the primary voltage is applied between the high and low voltage terminals or high voltage terminal and earth terminal.

3.2.16 rated voltage ratio of a capacitor divider (K_{CR})

the ratio of the voltage applied to the capacitor divider to the open-circuit intermediate voltage. [IEV 436-04-05]

NOTE 1 This ratio corresponds to the sum of the capacitances of the high voltage and intermediate voltage capacitors divided by the capacitance of the high voltage capacitor: $(C_1 + C_2) / C_1 = K_{CR}$.

NOTE 2 C_1 and C_2 include the stray capacitances, which are generally negligible.

3.2.17 capacitor losses

the active power dissipated in the capacitor. [IEV 436-04-10]

3.2.18 tangent of the loss angle (tanδ) of a capacitor

the ratio between the active power P_a and the reactive power P_r: $\tan\delta = P_a/P_r$.

3.2.19 temperature coefficient of capacitance (T_C)

the fractional change of the capacitance for a given change in temperature:

$$T_C = \frac{\frac{\Delta C}{\Delta T}}{C_{20\,°C}} \left[\frac{1}{K}\right]$$

ΔC represents the observed change in capacitance over the temperature interval ΔT

$C_{20°C}$ represents the capacitance measured at 20 °C.

NOTE The term $\Delta C/\Delta T$ according to this definition is usable only if the capacitance is an approximate linear function of the temperature in the range under consideration. If not, the temperature dependency of the capacitance should be shown in a graph or a table.

3.2.20 stray capacitance of the low voltage terminal

the stray capacitance between the low voltage terminal and the earth terminal.

3.2.21 stray conductance of the low voltage terminal

the stray conductance between the low voltage terminal and the earth terminal.

3.2.22 dielectric of a capacitor

the insulating material between the electrodes.

3.3 Electromagnetic unit definitions

3.3.1 electromagnetic unit

the component of a capacitor voltage transformer, connected between the intermediate voltage terminal and the earth terminal of the capacitor divider (or possibly directly connected to earth when a carrier-frequency coupling device is used) which supplies the secondary voltage.

NOTE An electromagnetic unit essentially comprises a transformer to reduce the intermediate voltage to the required value of secondary voltage, and a compensating inductance approximately equal, at rated frequency to the capacitive reactance of the two parts of the divider connected in parallel (C_1 + C_2). The compensating inductance may be incorporated wholly or partially in the transformer.

3.3.2 intermediate transformer

a voltage transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage.

3.3.3 compensating inductance

an inductance which is usually connected between the intermediate terminal and the high voltage terminal of the primary winding of the intermediate transformer or between earth terminal and the earth-side terminal of the primary winding of the intermediate transformer or incorporated in the primary and secondary windings of the intermediate transformer.

NOTE The design value L of the inductance is $L = \frac{1}{(C_1 + C_2)\cdot(2\pi f_R)^2}$

3.3.4 damping device

devices incorporated in the electromagnetic unit for the purposes of:

a) limiting overvoltages which may appear across one or more components;

b) and/or to prevent sustained ferro-resonance;

c) and/or to achieve a higher performance of the transient response of the capacitor voltage transformer.

3.4 Carrier-frequency accessories definitions

3.4.1 carrier-frequency accessories

circuit element intended to permit the injection of carrier frequency signal and which is connected between the low voltage terminal of a capacitor divider unit and earth, having an impedance which is insignificant at power frequency, but appreciable at the carrier frequency. (see figure A.2)

3.4.2 drain coil

an inductance which is connected between the low voltage terminal of a capacitor divider and earth. The impedance of the drain coil is insignificant at power frequency, but has a high value at the carrier frequency.

3.4.3 voltage limitation element

an element connected across the drain coil or between low voltage terminal of the capacitor voltage divider and earth to limit the overvoltages which appear across the drain coil:

a) at a short circuit between the high-voltage terminal and earth;

b) in the case where an impulse voltage is applied between the high voltage terminal and earth.

3.4.4 carrier earthing switch

a switch for earthing, when necessary, of the low voltage terminal.

4 General requirements

All capacitor voltage transformers shall be suitable for measuring purposes, but, in addition, certain types may be suitable for protection purposes. Capacitor voltage transformers for the dual purpose of measurement and protection shall comply with all clauses of this document.

5 Service conditions

Detailed information concerning classification of environmental conditions is given in IEC 60721 series.

5.1 Normal service conditions

5.1.1 Ambient air temperature

The capacitor voltage transformers are classified in three categories as given in table 1.

Table 1 – Rated ambient temperature categories

Category	Minimum temperature °C	Maximum temperature °C
–5/40	–5	40
–25/40	–25	40
–40/40	–40	40
NOTE In the choice of the temperature category, storage and transportation conditions should also be considered.		

5.1.2 Altitude

The altitude does not exceed 1 000 m.

5.1.3 Vibrations or earth tremors

Vibrations due to causes external to the capacitor voltage transformer or earth tremors are negligible.

5.1.4 Other service conditions for indoor capacitor voltage transformers

Other considered service conditions are the following:

a) the influence of solar radiation may be neglected;

b) the ambient air is not significantly polluted by dust, smoke, corrosive gases, vapours or salt;

c) the conditions of humidity are as follows:

   1) the average value of the relative humidity, measured during a period of 24 h, does not exceed 95 %;

   2) the average value of the water vapour pressure for a period of 24 h, does not exceed 2,2 kPa;

   3) the average value of the relative humidity, for a period of one month, does not exceed 90 %; the average value of the water vapour pressure, for a period of one month, does not exceed 1,8 kPa.

For these conditions, condensation may occasionally occur.

NOTE 1 Condensation be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2 To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, capacitor voltage transformers designed for such conditions should be used.

NOTE 3 Condensation may be prevented by special design of the housing, by suitable ventilation and heating or by the use of dehumidifying equipment.

5.1.5 Other service conditions for outdoor capacitor voltage transformers

Other considered service conditions are the following:

a) average value of the ambient air temperature, measured over a period of 24 h, does not exceed 35 °C;

b) solar radiation up to a level of 1 000 W/m^2 (on a clear day at noon) should be considered;

c) the ambient air may be polluted by dust, smoke, corrosive gases, vapours or salt. The pollution does not exceed the pollution levels given in table 6;

d) the wind pressure does not exceed 700 Pa (corresponding to 34 m/s wind speed);

e) account should be taken of the presence of condensation or precipitation.

5.2 Special service conditions

When capacitor voltage transformers may be used under conditions different from the normal service conditions given in 5.1, the user's requirements should refer to standardized steps as follows.

5.2.1 Altitude

For installation at an altitude higher than 1 000 m, the arcing distance under the standardized reference atmospheric conditions shall be determined by multiplying the withstand voltages required at the service location by factor k in accordance with figure 1.

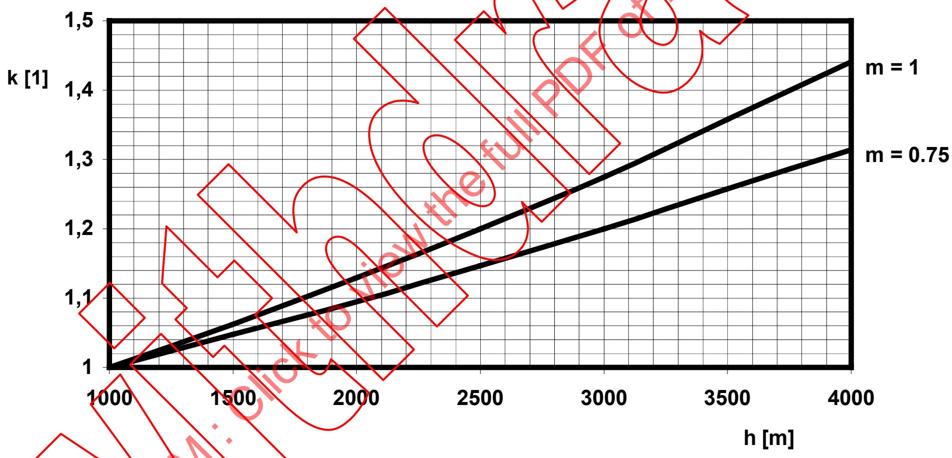


Figure 1 – Altitude correction factor for the insulation

These factors can be calculated with the following equation:

$$k = e^{m\,(H - 1000)/8150}$$

where

H is the altitude in metres;

m = 1 for power-frequency and lightning impulse voltage;

m = 0,75 for switching impulse voltage.

NOTE As for the internal insulation, the dielectric strength is not affected by altitude. The method for checking the external insulation shall be agreed between manufacturer and purchaser.

5.2.2 Ambient temperature

For installation in a place where the ambient temperature can be significantly outside the normal service condition range stated in 5.1.1, the preferred ranges of minimum and maximum temperature to be specified should be:

a) –50 °C and 40 °C for very cold climates;

b) –5 °C and 50 °C for very hot climates.

In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature may occur resulting in condensation even indoors.

NOTE Under certain conditions of solar radiation, appropriate measures e.g. roofing, forced ventilation, etc. may be necessary, in order not to exceed the specified temperature rises.

5.2.3 Earthquakes

Requirements and testing are under consideration.

5.3 System earthing

The considered system earthings are:

a) isolated neutral system (see 3.1.18);

b) resonant earthed system (see 3.1.21);

c) earthed neutral system (see 3.1.23):

   1) solidly earthed neutral system (see 3.1.19)

   2) impedance earthed (neutral) system (see 3.1.20).

6 Ratings

6.1 Standard values of rated frequency

Standard values are 50 and 60 Hz.

6.2 Standard values of rated voltages

6.2.1 Rated primary voltages U_{PR}

The standard values of rated primary voltage of a capacitor voltage transformer connected between one line of a three-phase system and earth or between a system neutral point and earth shall be $1/\sqrt{3}$ times the values of rated system voltage.

Preferred values are given in IEC 60038.

NOTE The performance of a capacitor voltage transformer as a measuring or protection transformer is based on the rated primary voltage U_{PR} whereas the rated insulation level is based on one of the highest voltages for equipment U_m of IEC 60071-1.

6.2.2 Rated secondary voltages

The rated secondary voltage U_{SR} shall be chosen according to the practice at the location where the transformer is to be used. The values given below are considered standard values for capacitor voltage transformers connected between one phase and earth in three-phase systems.

1) $\frac{100}{\sqrt{3}}$ V and $\frac{110}{\sqrt{3}}$ V;

2) Based on the current practice in some countries:

   a) $\frac{120}{\sqrt{3}}$ V for distribution systems;

   b) $\frac{115}{\sqrt{3}}$ V for transmission systems.

NOTE 1 The rated secondary voltage for windings intended to produce a residual voltage is given in 15.6.1.

NOTE 2 Whenever possible, the rated transformation ratio should be of a simple value.

6.3 Standard values of rated output

The standard values of rated output at a power factor of 1, expressed in volt-amperes, are: 1,0; 1,5; 2,5; 3,0; 5,0; 7,5 VA (burden range I, in 9.8).

The standard values of rated output at a power factor of 0.8 lagging, expressed in volt-amperes, are: 10; 15; 25; 30; 40; 50; 100 VA (burden range II, in 9.8).

The values underlined are preferred values.

NOTE For a given transformer, provided one of the values of rated output is standard and associated with a standard accuracy class, the declaration of other rated outputs, which may be non-standard values but associated with other standard classes, is not precluded.

6.4 Standard values of rated voltage factor

The voltage factor is determined by the maximum operating voltage which, in turn, is dependent on the system earthing conditions.

The standard voltage factors appropriate to the different earthing conditions are given in table 2 below, together with the permissible duration of maximum operating voltage (i.e. rated time).

Table 2 – Standard values of rated voltage factors for accuracy and thermal requirements

Rated voltage factor F_V	Rated time	Method of connecting the primary terminal and system earthing conditions
1,2	Continuous	Between phase and earth in an effectively earthed neutral system (3.1.23 a)
1,5	30 s	
1,2	Continuous	Between phase and earth in a non-effectively earthed neutral system (3.1.23 b) with automatic earth-fault tripping.
1,9	30 s	
1,2	Continuous	Between phase and earth in an isolated neutral system (3.1.18) without automatic earth-fault tripping or in a resonant earthed system (3.1.21) without automatic earth-fault tripping.
1,9	8 h	

NOTE 1 Reduced rated times are permissible by agreement between manufacturer and user.

NOTE 2 The thermal and accuracy requirements of a capacitor voltage transformer are based on the primary rated voltage whereas the rated insulation level is based on the highest voltage for equipment U_m (IEC 60071-1).

NOTE 3 The maximum operating voltage of a capacitor voltage transformer must be lower or equal to the highest voltage of equipment $\frac{U_m}{\sqrt{3}}$ or the rated primary voltage U_{PR} multiplied with the rated voltage factor 1.2 for continuous service, whichever is the lowest.

6.5 Limits of temperature rise

Unless otherwise specified, the temperature rise ΔT of a capacitor voltage transformer at the specified voltage, at rated frequency and at rated burden or at the highest rated burden if there are several rated burdens, at any power factor between 0,8 lagging and unity, shall not exceed the appropriate value given in table 3.

If ambient temperatures in excess of the values given in 5.1 are specified, the permissible temperature rise ΔT in table 3 shall be reduced by an amount equal to the excess ambient temperature.

If a capacitor voltage transformer is specified for service at an altitude in excess of 1 000 m and tested at an altitude below 1 000 m, the limits of temperature rise ΔT given in table 3 shall be reduced by the following amounts for each 100 m that the altitude at the operating site exceeds 1 000 m:

a) oil-immersed magnetic units: 0,4 %;

b) dry-type magnetic units: 0,5 %.

The altitude correction factor for the temperature rise $K_o = \frac{\Delta T_h}{\Delta T_{ho}}$ with

ΔT_h temperature rise at altitude h > 1000 m and

ΔT_{ho} limits of temperature rise ΔT specified in table 3 at altitudes ho ≤ 1000 m.

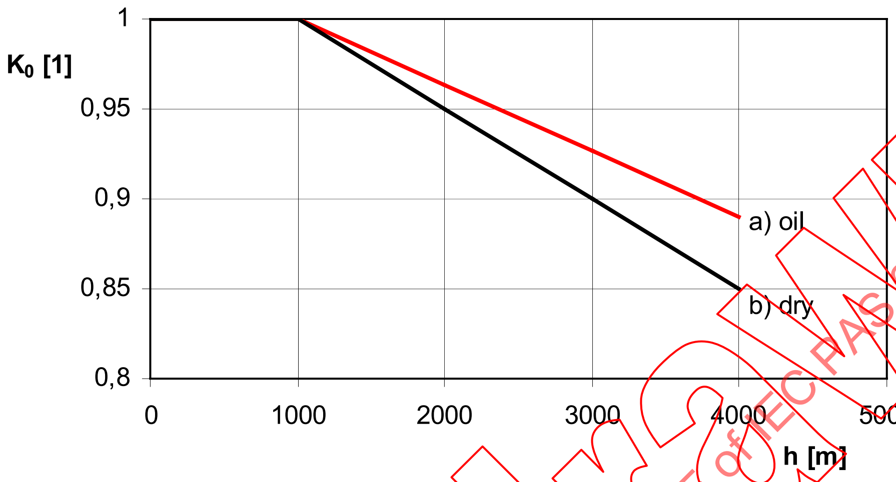


Figure 2 – Altitude correction factor for the temperature rise

The temperature rise ΔT of the windings is referred to the lowest class of insulation either of the winding itself or of the surrounding medium in which it is embedded. The maximum temperature rises of the insulation classes are as given in table 3.

Table 3 – Limits of temperature rise of windings

Class of insulation (in accordance with IEC 60085)	Maximum temperature rise ΔT in K
All classes, immersed in oil When the magnetic unit is not so fitted or arranged, the temperature rise ΔT of the oil at the top of the housing shall not exceed 50 K.	60
All classes, immersed in oil and hermetically sealed When the magnetic unit has an inert gas above the oil, or is hermetically sealed, the temperature rise ΔT of the oil at the top of the housing shall not exceed 55 K.	65
All classes, immersed in bituminous compound	50
Classes not immersed in oil or bituminous compound:	
Y	45
A	60
E	75
B	85
F	110
H	135
The temperature rise ΔT measured on the external surface of the core and other metallic parts which are in contact with, or adjacent to, insulation shall not exceed the appropriate values.	
NOTE For some materials (e.g. resin) the manufacturer should specify the relevant insulation class.	

7 Design requirements

7.1 Insulation requirements

The choice of the insulation level for capacitor voltage transformer shall be made in accordance with the standard insulation levels in table 4. The rated insulation levels shall be based on its highest voltage for equipment U_m.

Applied general rules:

– the rated positive wet switching impulse withstand voltage is the base for the determination of the minimum arcing distance (external insulation) of the capacitor voltage transformer;

– the strength of the external insulation is usually tested wet with the rated short duration power frequency withstand voltage (range I) or with the positive wet switching impulse withstand voltage (range II) (see 9.5);

– the value of the rated lightning impulse withstand voltage is one factor to determine the strength of the dielectric of the capacitors and the strength of the insulation of the electromagnetic unit;

– in IEC 60071-1, for each U_m only two standard withstand voltages are sufficient to define the standard insulation level for the equipment:

  - Range I: 72,5 kV ≤ U_m < 300 kV: rated lightning impulse withstand voltage and rated short-duration power-frequency withstand voltage;
  - Range II: 300 kV ≤ U_m ≤ 765 kV: rated switching and rated lightning impulse withstand voltages.

– due to the non-self-restoring internal insulation of capacitor voltage transformers, for range II three standard withstand voltages are specified in table 4. The short duration power frequency withstand voltage test has been specified for range II as a routine test with partial discharge measurement. The stress with a.c. voltage determines the long term behaviour of the non-self-restoring internal insulation of the capacitor voltage transformer;

– the rated short-duration power frequency withstand voltage test (column 4), with PD measurement in range II is an indication for the stress on the insulation of the capacitor voltage transformer;

– the rated insulation level is based on the highest voltage for equipment U_m, whereas the thermal and accuracy requirements of a voltage transformer are based on the primary rated voltage U_{PR}.

– The choice of the insulation level shall be made in accordance with 6.2.1 and IEC 60071-1. The protection zone of the ZnO arrester or the distance between the ZnO arrester and instrument transformer depending on the steepness of the voltage wave front shall be considered.

Table 4 – Standard insulation levels

Range	1 Highest voltage for equipment U_m (r.m.s.) kV	2 Rated switching impulse withstand voltage (peak) kV	3 Rated lightning impulse withstand voltage (peak) kV	4 Rated short-duration power-frequency withstand voltage (Routine test) (r.m.s.) kV
I	72,5		325	140
	100		450	185
	123		450	185
			550	230
	145		550	230
			650	275
	170		650	275
			750	325
	245		950	395
			1050	460
II	300	750	950	395
		850	1 050	460
	362	850	1 050	460
		950	1 175	510
	420	950	1 300	570
		1 050	1 425	630
	525	1 050	1 425	630
		1 175	1 550	680
	765	1 425	1 950	880
		1 550	2 100	975

NOTE 1 - For exposed installations it is recommended to choose the highest insulation level.

NOTE 2 - As the test voltage levels for U_m = 765 kV have not as yet been finally settled, some interchange between switching and lightning impulse test levels may become necessary.

7.2 Other insulation requirements

7.2.1 Low voltage terminal of the capacitor voltage divider

Capacitor voltage dividers with a low-voltage terminal shall be subjected for 1 min to a test voltage between the low-voltage and earth terminals. The test voltage shall be an a.c. voltage of 4 kV (r.m.s. value).

7.2.2 Low voltage terminal exposed to weather

If the low voltage terminal is exposed to the weather, it shall be subjected for 1 min to an a.c. voltage of 10 kV (r.m.s. value) between the low-voltage and earth terminals.

– During this test the magnetic unit is not disconnected.

NOTE The test voltages are applicable to capacitor voltage transformers with and without carrier-frequency accessories with overvoltage protection.

– If a protection gap between the low voltage terminal and earth is incorporated, it should be prevented from functioning during the tests. The carrier frequency accessories should be disconnected during the tests.

– If the test voltage is too low for the insulation co-ordination of the carrier-frequency accessories with the low voltage terminal, a higher value may be agreed upon the request of the purchaser.

7.2.3 Partial discharges

The partial discharge level shall not exceed the limits specified in table 5 at the partial discharge test voltage specified in the same table, after a pre-stressing performed according to the procedures of 10.2.3.2.

Partial discharge requirements are applicable to the complete capacitor voltage divider, or to a capacitor unit which is a part of a stack or to a capacitor stack which is a part of the capacitor voltage divider.

The partial discharge measurement is performed with the electromagnetic unit disconnected. The low electrical stress of the insulation in the electromagnetic unit doesn’t require a partial discharge measurement.

Table 5 – Partial discharge test voltages and permissible levels

Type of earthing of the system	PD test voltage (r.m.s.)	Permissible PD level (pC) Insulation immersed in liquid
Earthed neutral system	U_m	10
	$\frac{1,2\,U_m}{\sqrt{3}}$	5
Insulated or non-effectively earthed neutral system	$1,2\,U_m$	10
	$\frac{1,2\,U_m}{\sqrt{3}}$	5

NOTE 1 If the neutral system is not defined, the values given for isolated or non effectively earthed systems are valid.

NOTE 2 The permissible PD level is also valid for frequencies different from the system frequency.

NOTE 3 If only parts of the capacitor voltage divider are tested, the value of the test voltage will be equal to :

$$1,05 \times \text{test voltage of the CVT} \times \frac{\text{rated voltage of the unit}}{\text{rated voltage of the CVT}}$$

or

$$1,05 \times \text{test voltage of the CVT} \times \frac{\text{rated voltage of the stack}}{\text{rated voltage of the CVT}}$$

7.2.4 Chopped lightning impulse test

The test is intended to check the internal connections of the capacitor.

If additionally specified, the complete capacitor voltage transformer shall also be capable of withstanding a chopped lightning impulse voltage having a peak value of 115 % of the rated lightning impulse voltage.

7.2.5 Capacitance at power frequency

The capacitance *C* of a unit, a stack and a capacitor voltage divider shall not differ from the rated capacitance by more than –5 % to +10 %. The ratio of the capacitances of any two units forming part of a capacitor stack shall not differ by more than 5 % from the reciprocal ratio of the rated voltages of the units.

NOTE 1 $C = \frac{C_o}{n}$

where

n is the number of elements in series

C_o is the capacitance of one element

NOTE 2 The actual capacitance should be measured, or referred to, at the temperature at which the rated capacitance is defined.

7.2.6 Losses of the capacitor at power frequency

The requirements relating to capacitor losses, expressed as tanδ measured at 10 kV and 0,9 to 1,1 times the U_{PR} may be agreed upon between manufacturer and purchaser.

NOTE 1 The purpose is to check the uniformity of the production. Limits for the permissible variations may be the subject of an agreement between manufacturer and purchaser.

NOTE 2 The tanδ value is dependent on the insulation design and the voltage, the temperature and the measuring frequency.

NOTE 3 The tanδ value of certain types of dielectrics is a function of the energization time before the measurement.

NOTE 4 The losses of the capacitor are an indication of the drying and impregnation process.

NOTE 5 For information typical tanδ values are for dielectrics, which are impregnated with mineral oil or synthetic oil, at 20 °C (293 K):

a) Paper: $\leq 5 \cdot 10^{-3}$

b) Mixed: film-paper-film and paper-film-paper $\leq 2 \cdot 10^{-3}$

c) Film: $\leq 1 \cdot 10^{-3}$

7.2.7 Electromagnetic unit

7.2.7.1 Insulation level

a) The rated lightning impulse withstand voltage of the electromagnetic unit shall be equal to the:

$$\text{test impulse voltage of the CVT times } \frac{C_1}{C_1 + C_2} \text{ (peak)}$$

b) The rated short-duration power-frequency withstand voltage of the electromagnetic unit shall be equal to:

$$U_{PR} \times 3{,}3 \times \frac{C_1}{C_1 + C_2} \text{ (r.m.s.)}$$

NOTE 1 The tests a) can be performed on a complete capacitor voltage transformer.

NOTE 2 For the test b) the electromagnetic unit may be disconnected from the capacitor divider.

NOTE 3 The factor 3.3 is fixed for all U_m values and covers the worst case. (The factor $3{,}3 = \sqrt{3} \times \frac{140\,\text{kV}}{72.5\,\text{kV}} \approx \frac{\sqrt{3} \cdot 275\,\text{kV}}{145\,\text{kV}}$ is the correlation factor between a.c. test voltage and U_m.)

7.2.7.2 Between-section insulation requirements

For windings divided into two or more sections, the between-section insulation shall be capable of withstanding a rated power-frequency short-duration withstand voltage of 3 kV r.m.s. for 1 min.

7.2.7.3 Secondary windings insulation requirements

The winding insulation shall be capable of withstanding a rated power-frequency short-duration withstand voltage of 3 kV r.m.s. for 1 min.

7.2.8 External insulation requirements

For outdoor insulation susceptible to contamination, the minimum rated specific creepage distance measured on the insulation surface in millimetres is given in table 6.

Table 6 – Creepage distance

Pollution level	Minimum rated specific creepage distance 1) mm/kV 2)	Creepage distance / Arcing distance
I Light	16	≤ 3,5
II Medium	20	≤ 3,5
III Heavy	25	≤ 4,0
IV Very heavy	31	≤ 4,0

1) For the actual creepage distance, the specified manufacturing tolerances are applicable (see IEC 60233).

2) Ratio of the creepage distance measured in millimetres between phase and earth over the r.m.s. phase to phase value of the highest voltage in kV for the equipment U_m (see IEC 60071-1). For other information and manufacturing tolerances on the creepage distance see IEC 60815.

NOTE 1 It is recognized that the performance of surface insulation is greatly affected by insulator shape.

NOTE 2 In very lightly polluted areas, specific rated creepage distances lower than 16 mm/kV can be used depending on service experience. 12 mm/kV seems to be a lower limit.

NOTE 3 In the case of exceptional pollution severity, a specific rated creepage distance of 31 mm/kV may not be adequate. Depending on service experience and/or on laboratory test results, a higher value of specific creepage distance can be used, but in some instances the practicability of washing may have to be considered.

NOTE 4 The values are for procelain insulators. Composite insulators exist which have better performance against pollution, according to IEC 61462.

7.3 Short-circuit withstand capability

The capacitor voltage transformer shall be designed and constructed to withstand without damage, when energized at rated voltage, the mechanical, electrical and thermal effects of an external short-circuit at the secondary winding(s) for the duration of 1 s.

7.4 Ferro-Resonance

7.4.1 General

At any voltage below $F_V \cdot U_{PR}$ and at any burden between 0 and rated burden, the ferro-resonance of the CVT incepted by switching operations or transients on the primary or secondary terminals shall not be sustained.

7.4.2 Transients of ferro-resonance oscillations

$\hat{\varepsilon}_F$: Maximum instantaneous error

$\hat{U}_S$: Secondary voltage (peak)

U_P : Primary voltage (r.m.s.)

U_{PR} : Rated primary voltage (r.m.s.)

K_R : Transformation ratio

T_F : Duration of ferro-resonance

$$\hat{\varepsilon}_F = \frac{\hat{U}_S(T_F) - \dfrac{\sqrt{2}\cdot U_P}{K_R}}{\dfrac{\sqrt{2}\cdot U_P}{K_R}} = \frac{K_R \cdot \hat{U}_S(T_F) - \sqrt{2}\cdot U_P}{\sqrt{2}\cdot U_P}$$

Maximum instantaneous error $\hat{\varepsilon}_F$ after duration T_F :

a) Effectively earthed neutral system

Table 7a – Ferro-resonance requirements

Primary voltage U_p (r.m.s.)	Ferro-resonance oscillation Duration T_F s	Error $\hat{\varepsilon}_F$ after duration T_F %
0,8 · U_{PR}	≤ 0,5	≤ 10
1,0 · U_{PR}	≤ 0,5	≤ 10
1,2 · U_{PR}	≤ 0,5	≤ 10
1,5 · U_{PR}	≤ 2	≤ 10

b) Non-effectively earthed neutral system or isolated neutral system

Table 7b – Ferro-resonance requirements

Primary voltage U_p (r.m.s.)	Ferro-resonance oscillation Duration T_F s	Error $\hat{\varepsilon}_F$ after duration T_F %
0,8 · U_{PR}	≤ 0,5	≤ 10
1,0 · U_{PR}	≤ 0,5	≤ 10
1,2 · U_{PR}	≤ 0,5	≤ 10
1,9 · U_{PR}	≤ 2	≤ 10

7.5 RIV and TO requirements

7.5.1 Radio interference voltage (RIV)

This requirement applies to capacitor voltage transformers having $U_m \geq 123$ kV to be installed in air-insulated substation. The radio interference voltage shall not exceed 2500 µV at
$1,1\ U_m / \sqrt{3}$.

NOTE This requirement is included to meet some electromagnetic compatibility regulations.

7.5.2 Transmitted overvoltage (TO)

The overvoltages transmitted from the primary to the secondary terminals shall not exceed the values given in table 8 under test and measuring conditions described in IEC 60044-2.

Type A impulse requirement applies to capacitor voltage transformers for air-insulated substations, while impulse B requirement applies to capacitor voltage transformers installed in gas insulated metal-enclosed substations (GIS).

NOTE 1 This requirement is included to meet some electromagnetic compability regulations.

NOTE 2 Type A impulse is representative of voltage oscillations due to spark-gap flashover and switchgear operation. Type B is representative of the steep front impulses produced during switchgear operations.

Table 8 – Transmitted overvoltage requirements

Type of impulse	A	B
Peak value of the applied voltage (U_p)	$1{,}6\ \frac{\sqrt{2}\ U_m}{\sqrt{3}}$	$1{,}6\ \frac{\sqrt{2}\ U_m}{\sqrt{3}}$
Wave shape characteristics :		
– conventional front time (T_1)	0,50 µs ± 20%	–
– time to half-value (T_2)	≥ 50 µs	–
– front time (T_1)	–	10 ns ± 20%
– tail length (T_2)	–	>100 ns
Transmitted overvoltage peak value limits (U_s)	1,6 kV	1,6 kV

7.6 Mechanical requirements

Free standing capacitor voltage transformers shall be capable of withstanding the static test loads given in table 9.

The specified test loads are intended to be applied in any direction to the primary terminals.

Table 9 – Static withstand test loads

Highest voltage for equipment U_m kV	Static withstand test load F_R N		
	Capacitor voltage transformers with:		
	Voltage terminals	through current terminals Load class I	through current terminals Load class II
72,5 to 100	500	1 250	2 500
123 to 170	1 000	2 000	3 000
245 to 362	1 250	2 500	4 000
≥ 420	1 500	4 000	5 000

NOTE 1 This requirements do not apply to suspended capacitor voltage transformers.

NOTE 2 The sum of the loads acting in normal operating conditions should not exceed 50 % of the specified withstand test load.

NOTE 3 In some applications capacitor voltage transformers with through current terminals should withstand rarely occurring extreme dynamic loads (e.g. short circuits) not exceeding 1,4 times the static test load.

NOTE 4 The suspension system of a capacitor voltage transformer or of a capacitor divider should be so designed to withstand a tensile stress of at least the mass in kg of a capacitor voltage transformer or of a capacitor divider, with a safety factor of 2,5, multiplied by 9,81 to get the corresponding force in newtons.

NOTE 5 If the capacitor voltage transformer is used to support a line trap, other test loads should be agreed between manufacturer and purchaser.

NOTE 6 For some application it may be necessary to establish the resistance to rotation of the primary terminals. The moment to be applied during the test shall be agreed between manufacturer and purchaser.

7.7 Tightness of capacitor voltage divider and electromagnetic unit

7.7.1 Capacitor voltage divider

A capacitor unit or the complete assembled capacitor voltage divider shall be tight in the full temperature range specified for the applicable temperature category.

7.7.2 Electromagnetic unit

The electromagnetic unit shall be tight in the full temperature range specified for the applicable temperature category.

8 Classification of tests

The tests specified in this document are classified as type tests, routine tests and special tests. The type and routine tests shall be carried out in the same sequency as outlined in the flow chart (see figure 3). At the beginning and at the end of the test sequence, capacitance C, tanδ and accuracy shall be measured.

Type test

A test made on one transformer or two transformers of each type to demonstrate that all transformers made according to the same specification comply with the requirements not covered by routine tests.

NOTE 1 A type test may also be considered valid if it is made on a transformer which has minor deviations. Such deviations should be subject to agreement between manufacturer and purchaser.

NOTE 2 The type test must follow the procedure as specified in the flow chart of figure 3.

Routine test

A test to which each individual transformer is subjected.

Special test

A test other than a type test or a routine test, that shall be performed upon agreement between manufacturer and purchaser.

8.1 Type tests

The following tests are type tests. For details, reference should be made to the relevant subclauses:

a) accuracy check (10.6);

b) temperature rise test (9.1);

c) capacitance and tanδ measurement at power-frequency (9.2);

d) chopped impulse test (9.4.3);

e) EMC radio interference voltage (RIV) tests, if applicable (9.10);

f) short circuit withstand capability test (9.3);

g) lightning impulse test (9.4.2);

h) switching impulse test under wet conditions for the voltage range ≥ 300 kV (9.5.2);

i) wet test for outdoor type transformers with AC voltage for the voltage range < 300 kV (9.5.1);

j) transient response test (9.9) (valid only for protection capacitor voltage transformers);

k) ferro-resonance test (9.6);

l) tightness of electromagnetic unit (9.7);

m) accuracy tests (9.8).

After the capacitor voltage transformers have been subjected to the dielectric type tests of 8.1, they shall be subjected to all routine tests of 8.2.

Repeated power frequency tests shall be performed at 80 % of the specified test voltage. The type tests can be carried out on one or two capacitor voltage transformer according to the sequence of the flow chart given in figure 3.

The capacitance C of a unit or a stack or a capacitor voltage divider shall not change by more than $\frac{\Delta C}{C} \leq \frac{1}{\mathrm{n}} = \frac{C}{C_{\mathrm{o}}}$ during any test procedures (7.2.5).

The choice of one or two transformers is left to the manufacturer.

The type test report shall include the results of the routine tests.

NOTE 1 ΔC is the measured change of the capacitance C.

NOTE 2 By an agreement between the manufacturer and the purchaser the order of the test sequence (figure 3) can be modified.

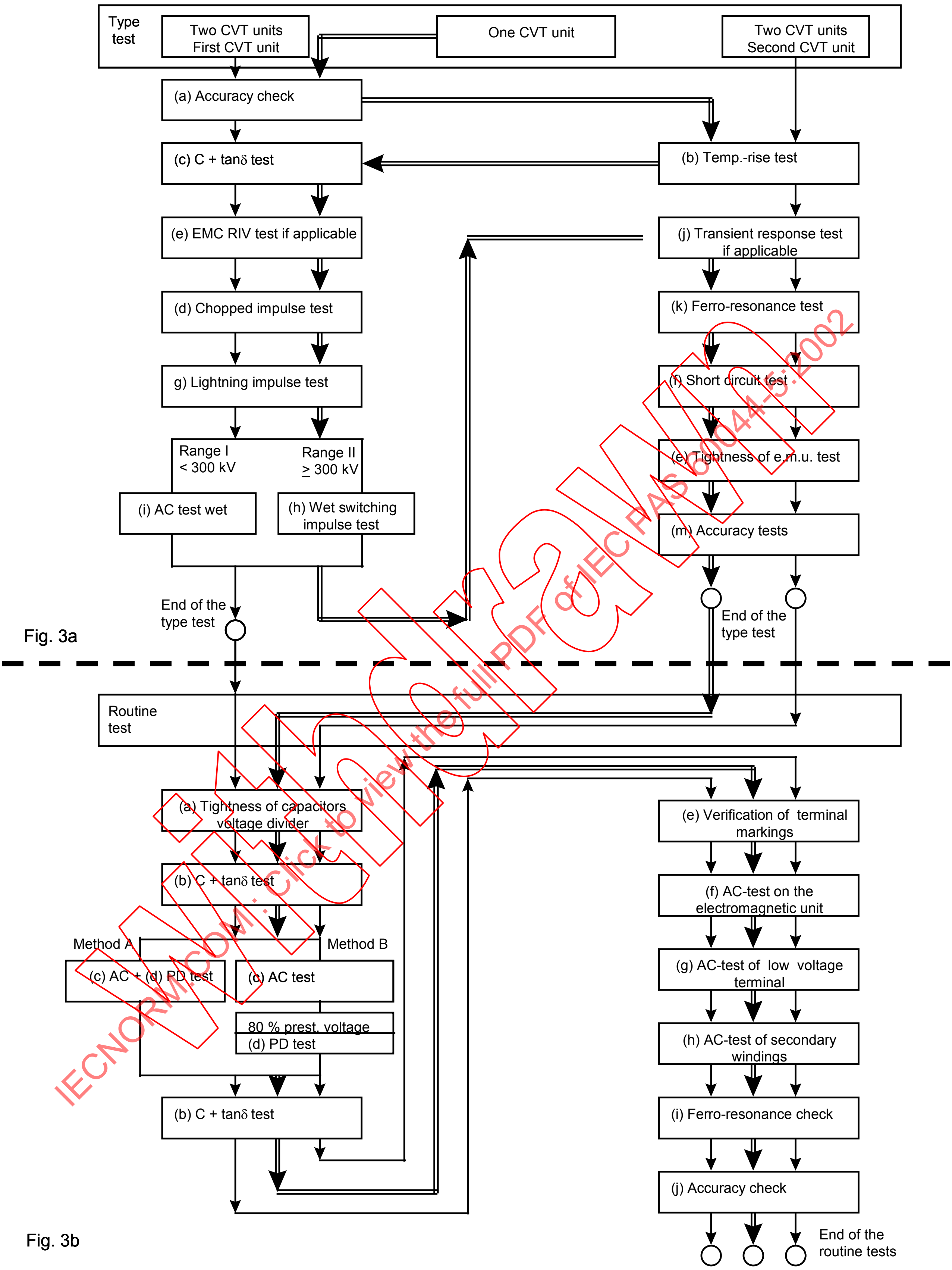


Figure 3 – Flow charts test sequence to be applied when performing the type test (figure 3a) and routine test (figure 3b)

8.2 Routine tests

The following tests are routine tests. For details, reference should be made to the relevant sub-clauses:

a) tightness of capacitor voltage divider (10.1);

b) capacitance and tanδ measurement at power-frequency (9.2);

c) power-frequency withstand test (10.2);

d) measurement of partial discharges (10.2.3);

e) verification of terminal markings (10.3);

f) power-frequency withstand tests on the electromagnetic unit (10.4);

g) power-frequency withstand test on low voltage terminal (10.2.4);

h) power-frequency withstand tests on secondary windings (10.4.2);

i) ferro-resonance check (10.5);

j) accuracy check (determination of errors) (10.6).

Apart from the fact that determination of errors j) shall be performed after the tests of items c), d), e), f), g) and h) the order or possible combination of the other tests is not standardized.

Repeated power-frequency tests shall be performed at 80 % of the specified test voltage.

Non repeated power-frequency tests shall be performed at 100 % of the specified test voltage.

8.3 Special tests

The following tests are special tests. For details, reference should be made to the relevant sub-clause:

a) measurement of the transmission factor of high frequency overvoltages (11.1);

b) mechanical strength test (11.2);

c) determination of the temperature coefficient (11.3);

d) tightness design test of capacitor units (11.4).

8.4 Test sequence for one or two units

Flow chart test sequence shall be considered mandatory (see figure 3).

NOTE Small modification of the test sequence shall be agreed between manufacturer and purchaser.

9 Type Test

9.1 Temperature-rise test

The test shall be made to prove compliance with 6.5.

The test can be performed on the complete capacitor voltage transformer or on the electromagnetic unit alone. When performed on the complete capacitor voltage transformer the primary voltage U_P shall be adjusted in accordance with table 10.

When performed on the electromagnetic unit the intermediate transformer shall be adjusted in such a way to have a secondary voltage U_S in accordance with table 10.

The temperature-rise test shall be performed with the rated burden or with the highest rated burden, if there are several rated burdens (6.5). The temperature must be recorded.

When there is more than one secondary winding, the test shall be made with the appropriate rated burden connected to each secondary winding simultaneously, unless otherwise agreed between manufacturer and purchaser.

The residual voltage winding shall be loaded in accordance with 15.6.5.1.

The test site ambient temperature shall be between 10 °C and 30 °C.

The capacitor voltage transformers or the electromagnetic unit alone irrespective of voltage factor and time rating shall be tested at 1,2 times the rated primary voltage. The secondary side must be at the corresponding value. The test shall be continued until the temperature (of the electromagnetic unit) has reached a steady state.

The electromagnetic unit can be considered in steady state conditions when the rate of temperature rise does not exceed 1 K per hour. The temperature rise of the windings shall be determined by the resistance variation method.

The temperature rise of parts other than windings may be measured by thermometers or thermocouples.

The ambient temperature can be measured by thermometers or thermocouples immersed in temperature insulation material, so that the system has a thermal time constant of the same order of the electromagnetic unit one.

Table 10 – Test voltage for temperature rise test

Voltage factor	F_V = 1,2		F_V = 1,5 or 1,9		F_V = 1,9		Thermal limiting output [1)]	
Test voltage with rated burden until the temperature rise is below 1 K/h.	Electro-magnetic unit	Complete capacitor voltage transformer	Electro-magnetic unit	Complete capacitor voltage transformer	Electro-magnetic unit	Complete capacitor voltage transformer	Electro-magnetic unit	Complete capacitor voltage transformer
	$U_S = \frac{1,2 U_{PR}}{K_R}$	$U_P = 1,2\ U_{PR}$	$U_S = \frac{1,2 U_{PR}}{K_R}$	$U_P = 1,2\ U_{PR}$	$U_S = \frac{1,2 U_{PR}}{K_R}$	$U_P = 1,2\ U_{PR}$	$U_S = \frac{1,2 U_{PR}}{K_R}$	$U_P = 1,2\ U_{PR}$
Test voltage for the last period of the test	–	–	$U_S = \frac{F_V \cdot U_{PR}}{K_R}$	$U_P = F_V \cdot U_{PR}$	$U_S = \frac{1,9\ U_{PR}}{K_R}$	$U_P = 1,9\ U_{PR}$	Thermal limiting output for specified windings separately (6.5)	
Duration	continuous		30 s		8 h			
1) = Additional test if a thermal limiting output is specified.								

9.2 Capacitance and tanδ measurement at power-frequency

9.2.1 Capacitance measurement

The test may be carried out on the capacitor voltage divider, or on a capacitor stack or on separate units. During this test the electromagnetic unit shall be disconnected.

The capacitance shall be measured using a method that excludes errors due to harmonics and to accessories in the measuring circuit. The uncertainty of the measuring method shall be indicated in the test report.

The final capacitance measurement shall be carried out at U_{PR} ± 10 % after the dielectric type and/or routine tests. The measurement shall be carried out at rated frequency or by agreement between 0,8 and 1,2 times of rated frequency.

In order to reveal any change in capacitance due to the puncture of one or more elements, a preliminary capacitance measurement shall be made before the dielectric type and/or routine tests, at a sufficient low voltage (less than 15 % of rated voltage) to ensure that no puncture of an element will occur.

NOTE 1 When there is an intermediate voltage terminal which is still accessible when the capacitor voltage transformer is completely assembled the following should be measured:

a) the capacitance between line and low voltage terminal or line and earth terminal,

b) the capacitance between the intermediate and low voltage terminals or intermediate and earth terminal.

NOTE 2 If the dielectric system of the capacitor is such that the measured capacitance varies with the voltage, it is more meaningful to repeat the capacitance measurement after the voltage test at the same voltage as that previously used and then at the measuring voltage which shall be not less than the rated voltage.

NOTE 3 If the number of elements in series in the tested unit is large, it may be difficult to ascertain whether no puncture has occurred because of the following uncertainties:

– reproducibility of the measurement.
– capacitance change caused by the mechanical forces on the elements during the dielectric tests.
– capacitance change caused by temperature difference of the capacitor before and after the tests.
– In this case, it should be proved by the manufacturer, for example by comparing the capacitance variations of capacitors of the same type and/or by calculation of the capacitance change caused by the temperature increase during the test, that no puncture had occurred. To reduce the measurement uncertainty it may be convenient to carry out these measurements on each unit.

9.2.2 Tanδ measurement

The capacitor losses (tanδ) shall be measured at U_{PR} ± 10 % together with the capacitance measurements, using a method that excludes errors due to harmonics and to accessories in the measuring circuit. The accuracy of the measuring method shall be given. The measurement shall be carried out at the rated frequency or by agreement at between 0,8 and 1,2 times rated frequency.

9.3 Short-circuit withstand capability test

This test shall be made to prove compliance with 7.3. For this test, the transformer shall be initially at a temperature between 10 °C and 30 °C. The capacitor voltage transformer shall be energized between high voltage terminal and earth and the short-circuit applied between the secondary terminals. One short-circuit shall be applied for the duration of 1 s. The current shall be measured and recorded.

NOTE This requirement applies also to the cases in which fuses are an integral part of the transformer.

During the short-circuit, the r.m.s. value of the applied voltage at the transformer terminals shall be not less than the rated primary voltage U_{PR} between phase and earth.

In the case of transformers provided with more than one secondary winding, or section, or with tappings, the test connection shall be agreed between manufacturer and purchaser.

The capacitor voltage transformer shall be deemed to have passed this test if, after cooling to ambient temperature, it satisfies the following requirements:

a) it is not visibly damaged;

b) its errors do not differ from those recorded before the tests by more than half the limits of error in its accuracy class and there is no significant change in the value of the capacitance;

c) it withstands the dielectric test specified in clause 10;

d) on examination, the insulation next to the surface of both primary and secondary windings of the electromagnetic unit does not show significant deterioration (e.g. carbonization).

The examination indicated in d) is not required if the current density in the winding does not exceed 160 A/mm^2 where the winding is of copper of conductivity not less than 97 % of the value given in IEC 60028. The current density is to be based on the measured symmetrical r.m.s. short-circuit current in the secondary winding.

NOTE For the examination of the variation of the capacitance see notes 1, 2 and 3 of 9.2.1.

9.4 Impulse tests

9.4.1 General

Impulse tests shall be performed on a complete capacitor voltage transformer in accordance with IEC 60060-1.

The test voltage shall be applied between high voltage terminal and earth. The earth terminal of the primary winding of the intermediate transformer, the low voltage terminal of the capacitor voltage divider, one of the terminals of each secondary winding and the frame shall be earthed during the test.

The impulse test generally consists of voltage application at reference and rated voltage levels. The reference impulse voltage shall be between 50 % and 75 % of the rated impulse withstand voltage.

The peak value and the wave-shape of the impulse voltage shall be recorded.

Evidence of insulation failure due to the test may be given by variation in the wave-shape at both reference and rated withstand voltage. For the failure detection the record of earth current (s) or of voltages appearing across the secondary winding (s), shall be taken in addition to the voltage record.

NOTE 1 A failure of the capacitor voltage transformer will be detected during the final routine test.

NOTE 2 The earth connections may be made through suitable current recording devices.

NOTE 3 For this test overvoltage limitation elements shall be disconnected.

9.4.2 Lightning-Impulse test

The waveform of the applied impulses shall be in accordance with IEC 60060-1, but the front time may be increased to a maximum of 8 μs, owing to the limitations of the testing equipment.

The test voltage shall have the appropriate value, given in table 4 depending on the highest voltage for equipment and the specified insulation level.

a) Range I: U_m < 300 kV

The test shall be performed with both positive and negative polarities. Fifteen consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The capacitor voltage transformer passes the test if for each polarity:

– no disruptive discharge occurs in the non-self-restoring internal insulation,

– no flashovers occur along the non-self-restoring external surface insulation,

– no more than two flashovers occur across the self-restoring external insulation,

– no other evidence of insulation failure is detected (e.g., variations in the waveshape of the recorded quantities for the same voltage level. Overvoltage limitation elements may have different influence on the waveshape at different voltage levels).

NOTE The application of 15 positive and 15 negative impulses is specified for testing the internal and external insulation. If other tests are agreed between manufacturer and purchaser to check the external insulation (see 9.5.1), the number of lightning impulses may be reduced to three of each polarity, not corrected for atmospheric conditions.

b) Range II: $U_m \geq$ 300 kV

The test shall be performed with both positive and negative polarities. Three consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The capacitor voltage transformer passes the test if:

– no disruptive discharge and no external breakdown occurs,

– no other evidence of insulation failure is detected (e.g., variations in the waveshape of the recorded quantities, taking into account the remarks for range I),

9.4.3 Chopped impulse test

The test shall be carried out on a complete capacitor voltage transformer with negative polarity only and combined with the negative polarity lightning impulse test in the manner described below.

The voltage shall be a standard lightning impulse as defined in IEC 60060-1, chopped after the crest value has been reached between 2 µs and 8 µs. The chopping circuit shall be so arranged that the amount of overswing of opposite polarity of the recorded impulse shall be limited to 30 % of the peak value. The lightning impulse shall be chopped with a suitable gap.

The test voltage of the full impulses shall have the appropriate value, given in table 4 depending on the highest voltage for the equipment and the specified insulation level. The chopped impulse test voltage shall have this value multiplied by 1,15.

The sequence of impulse applications shall be as follows:

a) for capacitor voltage transformers rated for U_m < 300 kV

– one full impulse

– two chopped impulses

– fourteen full impulses

b) for capacitor voltage transformers rated for $U_m \geq$ 300 kV

– one full impulse

– two chopped impulses

– two full impulses

Differences in waveshape of full wave applications before and after the chopped impulses are an indication of an internal fault. Flashovers during chopped impulses across self-restoring external insulation shall be disregarded in the evaluation of the behaviour of the insulation.

NOTE The chopped impulse test replaces the discharge test in IEC 60358.

9.5 Wet test for outdoor capacitor voltage transformer

The wetting procedure shall be in accordance with IEC 60060-1.

9.5.1 Capacitor voltage transformer having U_m < 300 kV (Range I)

The test shall be performed on a complete capacitor voltage transformer with rated short duration power frequency withstand voltage of the appropriate value given in table 4 depending on the highest voltage for equipment applying corrections for atmospheric conditions.

During the wet a.c. test the damping and protective devices shall be disconnected. If the intermediate connection between the electromagnetic unit and the capacitor divider is an inside type, the electromagnetic unit can be disconnected. If the intermediate connection between the electromagnetic unit and the capacitor divider is an outside type, the electromagnetic unit can be disconnected but then it must be wet tested separately with the a.c. voltage and duration as specified in 10.4.1.

9.5.2 Capacitor voltage transformer having $U_m \geq$ 300 kV (Range II)

The test shall be performed on a complete capacitor voltage transformer in accordance with 9.4.1 only with positive switching impulse voltage of the appropriate value given in table 4, depending on the highest voltage for the equipment and the rated insulation level.

Fifteen consecutive impulses, corrected for atmospheric conditions, shall be applied. Outdoor type transformers shall be subjected to the wet test. Dry test is not required.

The capacitor voltage transformer passes the test if:

– no disruptive discharge occurs in the non-self-restoring internal insulation,
– no flashovers occur along the non-self-restoring external surface insulation,
– no more than two flashovers occur across the self-restoring external insulation,
– no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities for the same voltage level).

NOTE Test arrangement and test connections in accordance with 9.4.1.

9.6 Ferro-resonance tests

The following tests shall be made on a complete capacitor voltage transformer or on the equivalent circuit to prove compliance with 7.4.2.

To realise the equivalent circuit, the actual capacitor or capacitors shall be used. The tests shall be made by short-circuiting the secondary terminals. The short circuit will be opened by a protective device chosen for this purpose by agreement between manufacturer and user. If no agreement has been made, the choice is left to the manufacturer.

If a fuse is used as a protection device, the time duration of the short circuit may be shorter than 0,1 s.

The burden of the capacitor voltage transformer after the short circuit shall be only that imposed by the recording equipment and shall not exceed 1 VA. The voltage of the power source at the high-voltage terminal, the secondary voltage and the short-circuit current during the test shall be recorded. Records shall be part of the test report.

During the test, the voltage of the power source shall not differ by more than 10 % from the voltage before short circuit and it shall remain substantially sinusoidal. The voltage drop over the short-circuit loop (contact resistance of the closed contactor included), measured directly at the secondary terminals of the capacitor voltage transformer, shall be less than 10 % of the voltage at the same terminals before the short circuit.

a) Ferro-resonance test for effectively earthed neutral system (7.4.2; table 7a): the test shall be made a minimum of 10 times at each primary voltage specified in table 7a.

b) Ferro-resonance test for non-effectively earthed neutral system or isolated neutral system (7.4.2; table 7b): the test shall be made a minimum of 10 times at each primary voltage specified in table 7b).

NOTE 1 If it is known that a saturable burden will be used in service, agreement should be made between user and manufacturer regarding the tests to be made at or near that burden.

NOTE 2 In order to ensure that the voltage of the power source does not differ during the test by more than 10 % from the voltage before short circuit, the short-circuit impedance of the supply circuit should be low.

9.7 Tightness test of a liquid-filled electromagnetic unit

The tightness test shall be a type test on the electromagnetic unit assembled as for normal service, filled with the liquid specified. A minimum pressure of (0,5 ± 0,1) x 10^5 *P*a above the maximum operating pressure shall be maintained during 8 h inside the e.m.u. The e.m.u. shall be considered to have successfully passed the test if there is no evidence of leakage.

9.8 Accuracy tests

9.8.1 General

The tests shall be made at rated frequency, at room temperature and at both extreme temperatures on a complete capacitor voltage transformer.

The equivalent circuit can be used for class ≥ 1.

For classes 0,5 and 0,2, the use of the equivalent circuit, or a calculation of the influence of temperature shall be agreed upon between user and manufacturer.

NOTE Tests at extreme temperatures on a complete capacitor voltage transformer are more severe than tests on the equivalent circuit or than a calculation of the temperature influence, but are very difficult to perform and are expensive. Tests on a complete capacitor voltage transformer also give the best possible indication concerning the measuring errors which may appear in service because of the changes in ambient temperature.

If the equivalent circuit is used, two measurements under identical conditions of voltage, burden, frequency and temperature – within the standard reference range – have to be carried out: once on the complete apparatus and once with the equivalent circuit.

The difference between the results of these two measurements must not exceed 20 % of the accuracy class (for instance 0,1 % and 4 min for accuracy class 0,5). It shall be taken into account by adding a margin of 20 %, when determining the errors of the complete capacitor voltage transformer at the limits of temperature and frequency.

Provided the temperature characteristics of the capacitor divider are known over the reference range of temperature, the errors at extreme values of temperature may be determined by calculations based on the measured results at one temperature and the temperature coefficient of the capacitor divider. Alternatively, a measurement at room temperature only may be performed on the equivalent circuit if the equivalent capacitance – e.g. a capacitor made especially for this purpose – is adapted to the capacitance values corresponding to the temperature extreme values, taking into account the temperature coefficient of the actual capacitor divider.

Tests at a constant value of temperature shall be made at the extreme values of frequency.

The actual values of test frequency and test temperature shall be part of the test report.

NOTE 1 The tests show the influence of burden, voltage and frequency as well as of temperature on the equivalent capacitance $C_1 + C_2$ on the value of error. Attention should be paid to the fact that the temperature effect on the inductive reactance and on the winding resistances of the electromagnetic unit can be determined only if the actual electromagnetic unit is subjected to the extreme temperatures. As a supplementary indication concerning changes in the capacitor divider ratio caused by temperature, it is recommended to measure the voltage errors and phase displacements before and immediately after - or during - the temperature-rise test of 9.1 performed as a direct test on the capacitor voltage transformer. In this case, the measurement as well as the temperature-rise test cannot be performed on the equivalent circuit or on the electromagnetic unit alone.

NOTE 2 Present day service experience has shown that capacitor voltage transformers may be used satisfactorily in the accuracy class 0,5. Sudden changes in temperature, particular weather and pollution conditions, stray capacitance and leakage currents may affect voltage errors and phase displacements. These influences, that can be evaluated only by theoretical considerations, are mostly important for capacitor voltage transformers of higher accuracy classes.

9.8.2 Measuring

To prove compliance with 14.4, type tests shall be made at 80 %, 100 % and 120 % of rated voltage, at standard reference range of frequency values for measuring and with values in accordance with table 11 at a power factor of 1 (Range I) or at a power factor of 0,8 lagging (Range II) on a complete capacitor voltage transformer.

Table 11 – Burden ranges for accuracy tests

Burden range	Preferred values of rated output in VA	Test values of rated output in %
I	1,0 2,5 5	0 and 100
II	10 25 50 100	25 and 100

9.8.3 Protection

To prove compliance with 15.4 type tests shall be made at 2 %, 5 % and 100 % of rated voltage and at rated voltage multiplied by the rated voltage factor (1,2, 1,5 or 1,9) at the two extreme values of the standard reference range of frequency for protection and with values of rated output in accordance with table 11 at a power factor of 1 (Range I) or at a power factor of 0,8 (Range II) lagging on a complete capacitor voltage transformer.

9.8.4 Measuring and protection

To prove compliance with 14.5 and 15.4, type tests shall be made simultaneously on all metering and protection windings as specified in 9.8.2 and 9.8.3.

Ordering transformers having two or more secondary windings, because of their interdependence, the user should specify output ranges, one for each winding, the upper limit of each output range corresponding to a standard rated output value. Each winding should fulfil its respective accuracy requirements within its output range, whilst at the same time the other winding(s) have an output of any value of its output range between 0 % and 100 %. In proving compliance with this requirement, it is sufficient to test at extreme values only. If no specification of output ranges is supplied, these ranges are deemed to be in accordance with table 11.

9.9 Transient response test

9.9.1 General

The test shall be carried out only on the capacitor voltage transformer for protection purposes. The test can be made on the complete capacitor voltage transformer or in the equivalent circuit made up with the actual capacitors.

The test shall be performed by short-circuiting the high voltage source at the actual primary voltage U_P or in the equivalent circuit at $U_P \cdot \frac{C_1}{C_1 + C_2}$ at 100 % and 25 % or 0 % of rated burden.

The burden shall be one of the following possibilities:

a) series burden composed of a pure resistance (range I) and an inductive reactance connected in series with a power factor of 0,8 (range II).

b) pure resistance burden.

The nature of the burden of the capacitor voltage transformer affects the transient response test results.

The measuring or other windings should be loaded as in practice but not higher than 100 % of the specified burden.

The test shall be made twice at the peak of the primary voltage and twice at the zero passage of primary voltage. The phase angle of the primary voltage shall not differ by more than ±20° of the peak and zero crossing.

NOTE 1 Modern microprocessor-based protection systems have a power factor of unity.

NOTE 2 By agreement between manufacturer and purchaser the test can be performed with burden as connected in practice.

9.9.2 The test values of the actual primary voltage (U_P)

U_P depends on the specified voltage factor F_V.

a) Continuous operation : 1,0 and 1,2 U_{PR}

b) Short duration overvoltages : 1,5 or 1,9 U_{PR}

For a) and b) see table 2.

The test circuit is shown in figure 4.

The primary and secondary voltages shall be recorded on an oscilloscope. The records shall be part of the test report.

NOTE 1 Requirements for transient response are given in 15.5.3.

NOTE 2 For measuring the input voltage *U* also a RC-divider can be used.

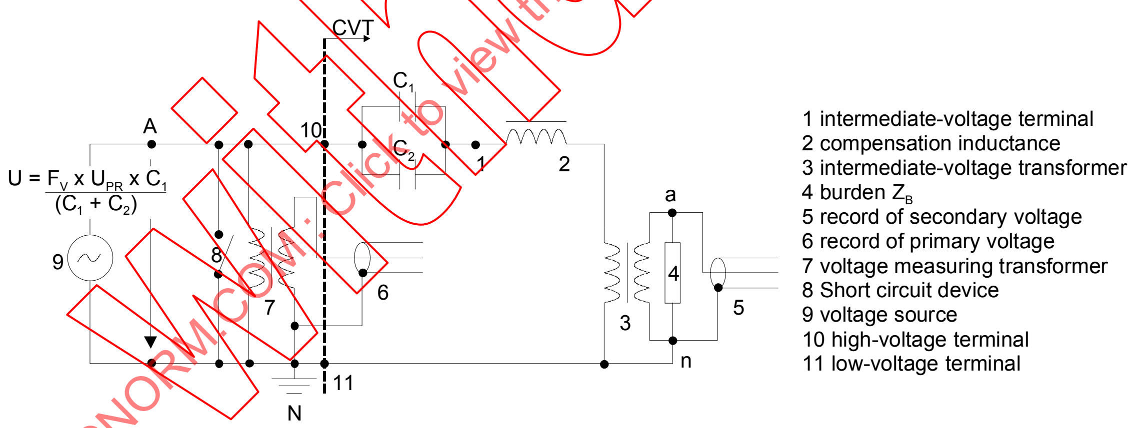


Figure 4 – Diagram of a capacitor voltage transformer for the transient response test using equivalent circuit method

Burdens for the transient response test.

a)

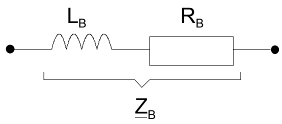


Figure 5 – Series burden

b)

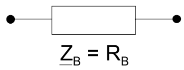


Figure 6 – Pure resistance

Impedance values for the series burden for the transient response test:

$$|Z_B| = \frac{U^2_{SR}}{S_R}$$

R_B	$\omega \cdot L_B$
0,8 $|Z_B|$	0,6 $|Z_B|$

where

S_R = rated burden in volt-ampere

U_{SR} = rated secondary voltage in volt

$|Z_B|$ = impedance in ohm

NOTE 1 The total impedance given by these values of R_B and $\omega \cdot L_B$ has a power factor of 0,8 lagging.

NOTE 2 The inductive reactance should be of a linear type, e.g. air-core reactance. The series resistance is composed of the equivalent series resistance of the inductive reactance (resistance of the winding) and of a separate resistance.

NOTE 3 The tolerance of the burden should be less than ±5 % for $|Z_B|$ and smaller than ±0,03 for the power factor.

9.10 Radio interference voltage test

The capacitor voltage transformer, complete with accessories, shall be dry and clean and at approximately the same temperature as the laboratory room in which the test is made.

The test shall be performed in accordance with IEC 60044-2.

In accordance with this document, the test should be performed under the following atmospheric conditions (see CISPR 18-2):

– temperature between 10 °C and 30 °C

– pressure between 0,870 × 10^5 *Pa* and 1,070 × 10^5 *Pa*.

– relative humidity between 45 % and 75 %

NOTE 1 By agreement between user and manufacturer, tests may be carried out under other atmospheric conditions.

NOTE 2 No correction factors for atmospheric conditions in accordance with IEC 60060-1 are applicable to radio interference tests.

A pre-stress voltage of 1,5 $U_m / \sqrt{3}$ shall be applied and maintained for 30 s.

Then the voltage shall be decreased to 1,1 $U_m / \sqrt{3}$ in about 10 s and maintained at this value for 30 s before measuring the radio interference voltage.

The capacitor voltage transformer shall be considered to have passed the test if the radio interference level at 1,1 $U_m / \sqrt{3}$ does not exceed the limit prescribed in 7.5.1.

NOTE By agreement between manufacturer and user, the RIV test as described above may be replaced by a partial discharge measurement applying the pre-stress and test voltages specified above. Any precaution taken during PD measurement performed in accordance with 10.2.3 for avoiding external discharges (i.e. shielding) shall be removed. In this case the balanced test circuit is not appropriate. Although there is no direct conversion between RIV microvolts and PD picocoulombs, the capacitor voltage transformer is considered to have passed the test if at 1,1 $U_m / \sqrt{3}$ the partial discharge level does not exceed 300 pC.

10 Routine tests

10.1 Tightness of the liquid-filled capacitor voltage divider

The tightness test shall be a routine test on the capacitor voltage divider or on separate units. The tightness test shall be done with a pressure of the liquid above the operating pressure, depending on the type of the expansion device for the capacitor units for 8 h.

NOTE On agreement between manufacturer and purchaser a special test can be specified to prove the tightness design of capacitor units (11.4).

10.2 Power-frequency withstand test and measurement of capacitance, tanδ and partial discharge

10.2.1 General

The power-frequency withstand test shall be performed in accordance with IEC 60060-1.

The test shall be carried out with voltages of substantially sinusoidal waveshape. The voltage shall be rapidly increased from a relatively low value to the test voltage value, maintained for 1 min, unless otherwise agreed, and then rapidly reduced to a relatively low value before being switched off. For this test the electromagnetic unit may be disconnected from the capacitor voltage divider.

Capacitance C, tanδ (9.2) and partial discharge measurements (10.2.3) can be made during the a.c. test of the capacitor divider or on the sub-systems.

10.2.2 AC-withstand test and measurement of *C* and tanδ on a capacitor voltage divider or on subsystems

Every capacitor voltage divider or capacitor stack or unit shall be subjected to an a.c. test and C and tanδ measurements. The test voltage being applied between the high voltage and the earth terminals when testing a capacitor stack, and between the terminals when testing a unit. When a low voltage terminal is provided, it shall be connected directly, or by a low impedance, to earth during this test. During the test, neither puncture (see 9.2.1) nor flashover shall occur.

The capacitance C shall be measured at a voltage less than 15 % of the rated primary voltage U_{PR} for reference before and after the power-frequency withstand test.

The value of the test voltage shall be equal to:

1,05 × test voltage of the stack × $\dfrac{\text{rated voltage of the unit}}{\text{rated voltage of the stack}}$ when testing a single unit forming part of a stack.

The value of the test voltage shall be equal to:

$$1{,}05 \times \text{test voltage of the complete CVT} \times \frac{\text{rated voltage of the stack}}{\text{rated voltage of the complete CVT}}$$

when testing a single stack forming part of a complete capacitor voltage transformer.

The test voltages for CVT's with U_m < 300 kV (Range I) or $U_m \geq$ 300 kV (Range II) shall have appropriate values given in table 4 depending on the highest voltage for equipment.

EXAMPLE:

– Highest voltage for equipment: U_m = 525 kV;

– Rated short-duration power-frequency withstand voltage: 680 kV;

Table 12 – Test voltages for units, stacks and complete capacitor voltage divider

Number		**Test voltage (r.m.s.) kV**		
Units	**Stacks**	**Unit**	**Stack**	**Complete capacitor voltage transformer**
2	–	340 · 1,05	–	680
4	2	170 · 1,05	340 · 1,05	680
6	3	113 · 1,05	227 · 1,05	680

Capacitance *C* and tanδ shall be measured at:

$$U_T = U_{PR} \times \frac{\text{rated voltage of the unit}}{\text{rated voltage of the stack}}$$ or

$$U_T = U_{PR} \times \frac{\text{rated voltage of the stack}}{\text{rated voltage of the complete capacitor voltage transformer}}$$

10.2.3 Partial discharge measurement

10.2.3.1 Test circuit and instrumentation

The test circuit and the instrumentation used shall be in accordance with IEC 60270. Some examples of test circuits are shown in figures 7 to 10.

The instrument used shall measure the apparent charge q expressed in pico-coulomb (pC). Its calibration shall be performed in the test circuit (see example in figure 10).

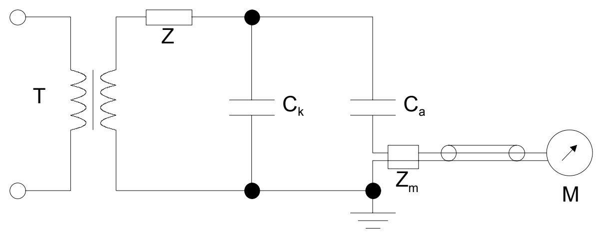
A wide-band instrument shall have a band width of at least 100 kHz, with an upper cut-off frequency not exceeding 1,2 MHz. Narrow-band instruments shall have their resonance frequency in the range 0,15 to 2 MHz. Preferred values should be in the range from 0,5 to 2 MHz but, if feasible, the measurement should be performed at the frequency which gives the highest sensitivity.

The sensitivity and noise-level shall allow to detect a partial discharge level of 5 pC to prove compliance with 7.2.3, table 5.

NOTE 1 Pulses that are known to be caused by external disturbances can be disregarded.

NOTE 2 For the suppression of external noise, the balanced test circuit is appropriate (figure 9)

NOTE 3 When electronic signal processing and recovery are used to reduce the background noise, this shall be demonstrated by varying its parameters such that it allows the detection of repetitive pulses.



T Test transformer

C_a Capacitor voltage divider to be tested

C_k Coupling capacitor ≈ 1 nF

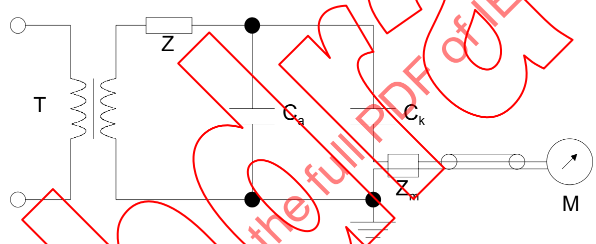
M PD measuring instrument

Z_m Measuring impedance

Z Filter

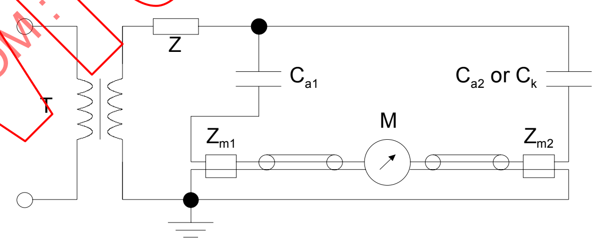
NOTE The filter is not present if C_K is the capacitance of the test transformer

Figure 7 – Test circuit



Symbols as in figure 7

Figure 8 – Alternative circuit



T Test transformer

C_{a1} Capacitor divider under test

C_{a2} Auxiliary object or C_k (Coupling capacitor)

M PD measuring instrument

Z_m Measuring impedance

Z Filter

NOTE The objects C_{a2} or C_k in the second bridge branch shall have a similar impedance as the capacitor voltage divider C_{a1} · C_{a2} can be another capacitor voltage divider of similar capacitance.

Figure 9 – Example of balanced test circuit

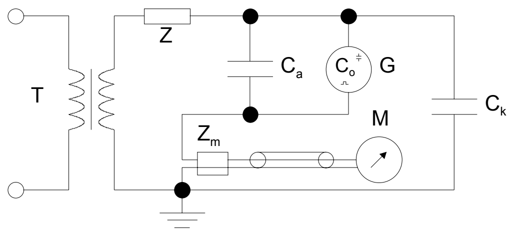


Figure 10 – Example of calibration circuit

Symbols as in figure 9

G Pulse generator with capacitance C_0

10.2.3.2 Test procedure for capacitor voltage divider or on sub-systems (see 10.2.2)

After a pre-stressing performed according to procedure A or B, the partial discharge test voltage specified in table 5 is applied and the corresponding partial discharge level shall be measured within 30 s.

The measured partial discharge level shall not exceed the limits specified in table 5.

Procedure A: The partial discharge test voltages are reached while decreasing the voltage after the power frequency withstand test.

Procedure B: The partial discharge test is performed after the a.c. voltage withstand test. The applied voltage is raised to 80 % of the withstand voltage, maintained for not less than 60 s, then reduced without interruption to the specified partial discharge test voltage.

If not otherwise specified, the choice of procedure is left to the manufacturer. The test method used shall be indicated in the test report.

10.2.4 AC-withstand test on low-voltage terminal of the capacitor voltage divider (7.2.1 and 7.2.2)

Capacitor voltage dividers with a low-voltage terminal shall be subjected for 1 min to a test voltage between the low-voltage and earth terminals. The test voltage shall be an a.c. voltage of 10 kV (r.m.s. value). If the low-voltage terminal is not exposed to the weather or if a carrier-frequency coupling device with overvoltage protection is part of the capacitor voltage transformer, the test voltage shall be an a.c. voltage of 4 kV (r.m.s. value).

– During this test the magnetic unit is not disconnected.

NOTE The test voltage is applicable to capacitor voltage transformers with and without carrier-frequency accessories with overvoltage protection.

– If a protection gap between low voltage terminal and earth is incorporated, it should be prevented from functioning during the test. The carrier frequency accessories should be disconnected during the tests.

– If the test voltage is too low for the insulation co-ordination of the carrier-frequency accessories with the low voltage terminal, a higher value may be agreed upon the request of the purchaser.

10.3 Verification of terminal markings

It shall be verified that the terminal markings are correct (13.1 and 13.2).

10.4 Power-frequency withstand tests on the electromagnetic unit

10.4.1 Insulation test of the electromagnetic unit

The test voltage shall be applied between the intermediate voltage terminal and earth. It shall have a rated short-duration power-frequency withstand voltage of

$$U_{PR} \times 3{,}3 \times \frac{C_1}{C_1 + C_2} \text{ (r.m.s.).}$$

The frequency of the test voltage may be increased above the rated value to prevent saturation of the core. The duration of the test shall be 1 min. If, however, the test frequency exceeds twice the rated frequency, the duration of the test may be reduced from 1 min. as follows:

$$\text{duration of test} = \frac{\text{(twice the rated frequency)}}{\text{test frequency}} \cdot 60 \text{ s}$$

with a minimum of 15 s.

NOTE If a protective device across the electromagnetic unit is incorporated, it should be prevented from functioning during the tests. Any protective gap across the carrier-frequency accessories should be short-circuited during the tests.

10.4.2 Tests between sections and on secondary windings

The test voltage shall have the appropriate values given in 7.2.7.2 and 7.2.7.3 respectively. The test voltage shall be applied for 1 min in turn between the terminals of each secondary winding or section and earth. The frame, case (if any), core (if intended to be earthed) and the terminals of all other windings or sections shall be connected together and to earth.

10.5 Ferro-resonance check

These tests shall be made on a complete capacitor voltage transformer or on the equivalent circuit.

The primary test voltage U_P, numbers of short-circuiting on the secondary terminals and the limits of the transients of the ferro-resonance oscillations are specified in table 13.

Table 13 – Ferro resonance check

Primary voltage U_p (r.m.s.)	Number of short-circuiting at the secondary terminals	Ferro-resonance oscillation duration T_F s	Error $\hat{\varepsilon}_F$ after duration T_F %
$0{,}8\ U_{PR}$	3	≤ 0,5	≤ 10
$F_V \cdot U_{PR}$	3	≤ 2	≤ 10

The test procedure must be in accordance with 9.6 with the exception of the number of voltages and short-circuits. The capacitor voltage transformer has passed the ferro-resonance check, if the duration and the error do not exceed the limits specified in table 13.

10.6 Accuracy check

The accuracy check shall be done with rated power-frequency, at ambient temperature and on the complete capacitor voltage transformer or on the equivalent circuit for the accuracy classes ≥ 1 in accordance with table 14.

NOTE 1 Notes for the equivalent circuit

a) The equivalent circuit can be used, if a comparison between the accuracy test on a complete transformer during type test and accuracy test in the equivalent circuit has shown that the difference between measured values is less than 20 % of the accuracy class limits.

b) To realize the equivalent circuit the actual capacitor or different capacitors can be used. If different capacitors are used they can be adjusted to the actual measured values.

NOTE 2 Complete CVT and equivalent circuit

a) The margin is to account for variations in error resulting from temperature and frequency when the transformer is used within its reference ranges of temperature and frequency. The allowance is determined by considering the worst case influence of temperature and frequency occurring simultaneously. This margin depends on the type of capacitor dielectric and on the design. In the error diagram of figure 11, 20 % + margin is indicated. The margin will be defined by the manufacturer.

b) If the accuracy check is done on a complete capacitor voltage transformer some margin will be added for the combined effect of frequency and temperature.

Table 14 – Accuracy check points (example)

Secondary winding (s)	Checking voltage	Test ranges of rated output in %			
		Range I Power factor 1 Standard values of rated output		Range II Power factor 0,8 (lagging) Standard values of rated output	
		1,0 ... ≤ 5 VA		≥ 10 ... 100 VA	
		Measuring	Protection	Measuring	Protection
one measuring winding	1 · U_{PR}	0	-	25	-
		100	-	100	-
one protection winding	0,05 · U_{PR}	-	0	-	25
		-	100	-	100
	F_V · U_{PR}	-	0	-	25
		-	100	-	100
one measuring and one protection winding	Measuring	0	0	25	0
	1 · U_{PR}	100	100	100	100
	Protection	0	0	0	25
	0,05 · U_{PR}	100	100	100	100
	Protection	0	0	0	25
	F_V · U_{PR}	100	100	100	100

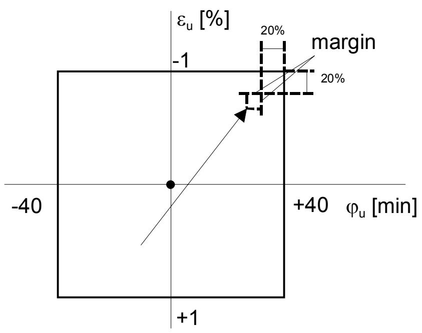


Figure 11 – Example of an error diagram of class 1 CVT for accuracy check with the equivalent circuit

11 Special Tests

11.1 Measurement of the transmission factor of high frequency overvoltages

The test and measuring conditions are described in IEC 60044-2.

The capacitor voltage transformer is considered to have passed the test if the value of the transmitted overvoltage does not exceed the limits given in table 8.

11.2 Mechanical strength test

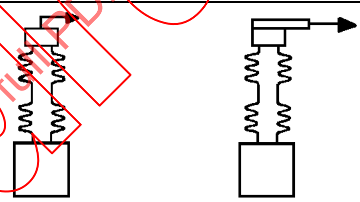
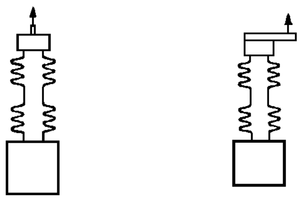
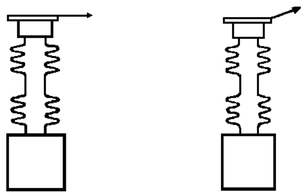
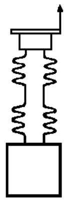
The tests are carried out to demonstrate if a capacitor voltage transformer is in compliance with the requirements specified in 7.6.

The capacitor voltage transformer shall be completely assembled and installed in vertical position with the frame rigidly fixed.

The test loads shall be applied for 1 min for each of the conditions indicated in table 15.

The capacitor voltage transformer shall be considered to have passed the test if there is no evidence of damage (deformation, rupture or leakage).

Table 15 – Modalities of application of the test loads to the line primary terminals

Type of capacitor voltage transformer	**Modality of application**	
With voltage terminal	Horizontal	
	Vertical	
With through current terminals	Horizontal to each terminal	
	Vertical to each terminal	
NOTE The test load shall be applied to the centre of the terminal.		

11.3 Determination of the temperature coefficient (T_C)

The determination of the temperature coefficients for the capacitance values of C_1 and C_2 and their tanδ values shall be performed according to IEC 60358.

11.4 Tightness design test of capacitor units

This test is performed to prove the quality of design of the capacitor unit tightness and the compliance with the requirement given in 7.7 and 10.1.

NOTE This test is not an ageing test. It is not intended to solve tightness problems due to ageing that have been observed with particular designs of capacitor voltage divider parts.

The test shall be done with a pressure of the liquid at least 10^5 *Pa* higher than the maximum operating pressure that could be reached under normal service conditions and at a temperature of 80 °C for 8 h.

The capacitor voltage divider shall be assembled as for normal service. The expansion device of the capacitor unit may be specially calibrated for the temperature test of 80 °C. Appropriate arrangement can be done to contain mechanical deformations due to the 10^5 *Pa* over-pressure.

The liquid filled capacitor voltage divider shall be considered to have passed the test if there is no evidence of leakage during and after the test.

12 Marking of the capacitor units

12.1 General

Warning plate

If the capacitor unit contains material that might pollute the environment or may be hazardous in any other way, the unit shall be equipped with a label according to the relevant laws of the country of the user, who is responsible for informing the manufacturer about such laws.

12.2 Marking

Rating plate

The following information shall be given on the rating plate of each capacitor unit:

1) manufacturer;
2) serial number and year of manufacture;
3) rated capacitance C_R in picofarads.

13 Terminal markings

13.1 General

These markings apply to a single-phase capacitor voltage transformer.

13.2 Markings

Terminal markings

Markings shall be in accordance with figures 12, 13, 14 and 15.

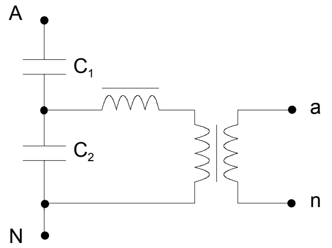


Figure 12 – Single-phase transformer with a neutral primary terminal and a single secondary

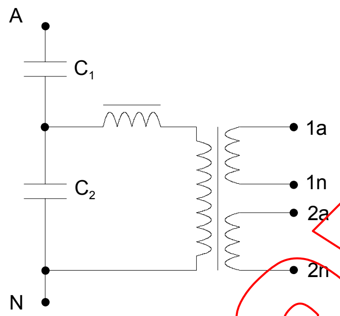


Figure 13 – Single-phase transformer with a neutral primary terminal and with two secondaries

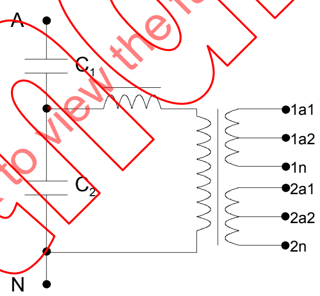


Figure 14 – Single-phase transformer with a neutral primary terminal and with two tapped secondaries

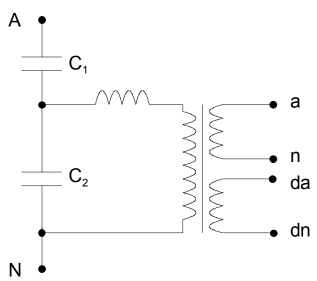


Figure 15 – Single-phase transformer with a neutral primary terminal, with one residual voltage winding and a single secondary

14 Additional requirements for measuring capacitor voltage transformer

14.1 Accuracy class designation

For measuring capacitor voltage transformers, the accuracy class is designated by the highest permissible percentage voltage error at rated voltage and with rated burden, prescribed for the accuracy class concerned.

14.2 Standard reference range of frequency

The standard reference range of frequency shall be from 99 % to 101 % of the rated frequency for accuracy classes for measurement.

14.3 Standard accuracy classes

The standard accuracy classes for single-phase metering capacitor voltage transformers are:

0,2 – 0,5 – 1,0 – 3,0

14.4 Limits of voltage error and phase displacement

The voltage error and phase displacement shall not exceed the values given in table 16 for the appropriate accuracy class at any value of temperature and frequency within the reference ranges and with burdens from 0 % to 100 % of rated value for rated burden range I or with burdens from 25 % to 100 % of rated value for rated burden range II.

Table 16 – Limits of voltage error and phase displacement for measuring capacitor voltage transformers

Accuracy class	Percentage voltage (ratio) error ε_u ±	Phase displacement φ_u ±	
		Minutes	Centiradians
0,2	0,2	10	0,3
0,5	0,5	20	0,6
1,0	1,0	40	1,2
3,0	3,0	Not specified	Not specified

NOTE 1 The input burden (input impedance) of a compensated bridge is very low (≈ 0) (very high).

NOTE 2 The power factor of the rated burden shall be in accordance with 9.8.2.

NOTE 3 For CVT's having two or more secondary windings (see 9.8). If one of the winding is loaded only occasionally for short periods or only used as a residual voltage winding its effect upon other windings may be neglected.

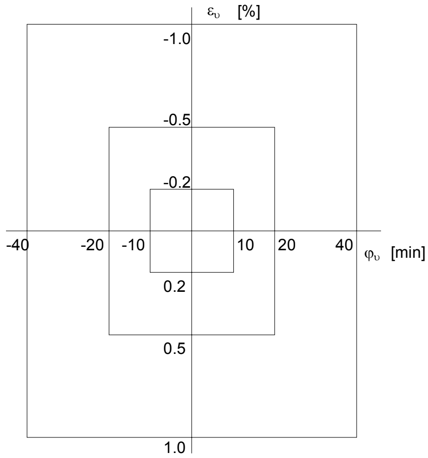


Figure 16 – Error diagram of a capacitor voltage transformer for accuracy classes 0,2, 0,5 and 1,0

14.5 Tests for accuracy

14.5.1 Type tests

To prove compliance with 14.4, type tests shall be made at 80 %, 100 % and 120 % of rated voltage, at the extreme values of the standard reference range of frequency (14.2) and at the upper and lower limits of rated outputs (9.8.1 and 9.8.2).

14.5.2 Routine tests

Routine tests for accuracy check shall be done at ambient temperature at a reduced number of voltages and/or burdens and at rated frequency, (see 10.6, table 14) provided it has been shown by type tests on a similar capacitor voltage transformer that such a reduced number of tests is sufficient to prove compliance with 14.4.

15 Additional requirements for protective capacitor voltage transformers

15.1 Accuracy class designation

The accuracy class for a protective capacitor voltage transformer is designated by the highest permissible percentage voltage error prescribed for the accuracy class concerned, from 5 % of rated voltage to a voltage corresponding to the rated voltage factor (6.4).

This expression is followed by the letter “P”. In 15.5 three additional classes for transient performance are introduced: T1, T2 and T3. Class 3PT1, for example, incorporates the performance of class 3 P and class T1 for transient performance.

15.2 Standard reference range of frequency

The standard reference range of frequency shall be from 96 % to 102 % for accuracy classes for protection.

15.3 Standard accuracy classes

The standard accuracy classes for protective capacitor voltage transformers are “3P” and “6P”.

15.4 Limits of voltage error and phase displacement

The voltage error and phase displacement shall not exceed the values given in table 17 for the appropriate accuracy class at 2 % and 5 % rated voltage and rated voltage multiplied by the rated voltage factor (1,2, 1,5 or 1,9), and at any value of temperature and frequency within the reference ranges and with burdens from 0 % to 100 % of rated value for burden range I or with burdens from 25 % to 100 % of rated value for burden range II.

NOTE 1 The power factor of rated burden shall be in accordance with 9.8.2.

NOTE 2 For CVT's having two or more windings (see 9.8.4). If one of the windings is loaded only occasionally for short periods or only used as a residual voltage winding, its effect upon other windings may be neglected.

NOTE 3 Where transformers have different error limits at 5 % of rated voltage and at the upper voltage limit (i.e. voltage corresponding to rated voltage factor 1,2, 1,5, 1,9), agreement should be made between manufacturer and purchaser.

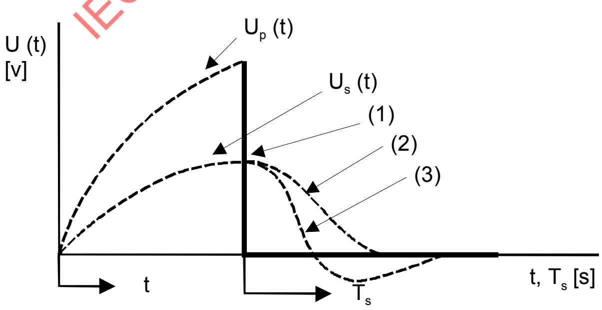
Table 17 – Limits of voltage error and phase displacement for protective capacitor voltage transformers

	Percent voltage (ratio) error at percentage of rated voltage ε_u ±				Phase displacement at percentage of rated voltage φ_u ±							
					Minutes				Centiradians			
Percentage of rated voltage / Protection classes	2	5	100	X	2	5	100	X	2	5	100	X
3P	6,0	3,0	3,0	3,0	240	120	120	120	7,0	3,5	3,5	3,5
6P	12,0	6,0	6,0	6,0	480	240	240	240	14,0	7,0	7,0	7,0
NOTE X = F_V × 100 (rated voltage factor multiplied by 100)												

15.5 Transient response

15.5.1 General

Characteristic of the transient response are the ratio secondary voltage $U_S(t)$ to the peak value of the secondary voltage $\sqrt{2}U_S$ before the application of the primary short circuit at a specified time T_S after application of the primary short circuit. The secondary voltage U_S = $U_S(t)$ after a short circuit of the primary voltage $U_P = U_P(t)$ can be represented as follows:



1) Short circuit of $U_P(t)$
2) Aperiodic damping of $U_S(t)$
3) Periodic damping of $U_S(t)$

Figure 17 – Transient response of a capacitor voltage transformer

15.5.2 equirements for transient response

Following a short circuit of the supply between the high-voltage terminal A and the low voltage terminal N connected to earth, the secondary voltage of a capacitor voltage transformer shall decay within a specified time T_S to a specified value of the peak voltage before application of the short circuit (see figure 17).

15.5.3 Standard transient response classes

Characteristic of the transient response is the ratio of secondary voltage $U_s(t)$ at a specified time T_S after application of a primary short circuit to the peak value of the secondary voltage $\sqrt{2}U_S$ before the application of the primary short circuit.

Table 18 – Standard values

Time T_S s	Ratio $\frac{\lvert U_s(t) \rvert}{\sqrt{2} \cdot U_S} \cdot 100\%$		
	Classes		
	3PT1 6PT1	**3PT2 6PT2**	**3PT3 6PT3**
$10 \cdot 10^{-3}$	–	≤ 25	≤ 4
$20 \cdot 10^{-3}$	≤ 10	≤ 10	≤ 2
$40 \cdot 10^{-3}$	< 10	≤ 2	≤ 2
$60 \cdot 10^{-3}$	< 10	≤ 0,6	≤ 2
$90 \cdot 10^{-3}$	< 10	≤ 0,2	≤ 2

NOTE 1 For a specified class the transient response of the secondary voltage U_S (t) can be aperiodic or periodic damped and a reliable damping device can be used.

NOTE 2 Capacitor voltage transformer, for transient response classes 3PT3 and 6PT3, needs the use of a damping device.

NOTE 3 Other values of the ratio and the time T_s can be agreed between manufacturer and purchaser.

NOTE 4 The choice of transient response class depends on characteristics of the specified protection relays.

If a damping device is used, the proof of the reliability of this device should be part of an agreement between manufacturer and purchaser.

15.5.4 Transient response type tests

The test shall be carried out in accordance with 9.9.

15.6 Requirements for secondary windings intended to produce a residual voltage

15.6.1 Rated secondary voltages

Rated secondary voltages of windings intended to be connected in broken delta with similar windings to produce a residual voltage are given in table 19.